An Experimental Study of

A Creative Constructivist Science Learning Cycle

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PREFACE

There have been continuous efforts to improve science education in schools in India and abroad . During 1970s, learning by enquiry and discovery were given preference . Hands-on laboratories and process skills became major foci for science programmes . However , this approach lacked proper balance between process skills and concept understanding and transfer because of the following reasons:

- learning comes as a result of external influence where students accept the knowledge without creating meaning in their minds.
- lack of interactions between prior and new knowledge
- lack of interactions between school knowledge and out-of-school knowledge necessary for conceptual transfer .

Recent reforms in science education call for constructivist approach where students are active rather than passive constructor of knowledge while creating meaning in their minds. The psychological constructivist approach relies very much on individual unguided constructions whereas the situated constructivist approach relies on social constructions. The present approach takes the middle path and defines creative constructivism and details a learning cycle where students enhance investigative, reasoning and communicative thinking skills . The

cycle offers students chance to explore the concepts through initiating questions and through hands-on enquiry activities. The students are guided by the observations, critical thinking through visiting the concepts in diverse situations and dialogue with others. They are involved in challenging design activities in novel contexts for conceptual transfer.

The learning cycle was tried out in schools in XI class, though this is applicable to all the classes in school situations. The report lists the theoretical rationale , data received from the try out through achievement tests, construction sheets, interviews, etc. , analysis and conclusions with appropriate appendices. This type of approach is found to be quite superior to the traditional one.

The report will be of interest and use to educational researchers, teachers, heads of schools, policy planners, etc. Suggestions for further improvement shall be welcome.

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I. INTRODUCTION

Which learning activities contribute to the learning of science concepts with understanding and to transfer this understanding to daily-life situations to avoid accumulation of inert knowledge? Answer to these questions are of paramount importance to the designing and use of innovative learning environments for science education in school settings. Traditionally, classroom experiences are predominantly organized on the basis of the behaviorist approach which emphasizes rote learning. It has been criticized that this type of learning is passive and the children accept the information without understanding i.e. without creating meanings in their minds. Moreover, the out-of-school knowledge is not well integrated into the school knowledge.

Science education is now increasingly finding a base on constructivist cognitive and social learning theories which consider a human being as an active constructor of knowledge based on his or her prior knowledge rather than as being passive recipient of environment stimuli. There have been, however, differing perspectives on the role of external environment among other issues on learning and development (Phillips, 1995; Bodner, 2001). Major science educational practices have been based on Piaget's cognitive developmental perspective. Bodner (2001) has

doubts whether a real world actually exists (ii) it prevents to say that student is wrong (iii) it ignores the role of teachers who influence learning. So simply teachers getting out of the way of students is not the right approach. The other learning theory of social constructions emphasizes the role of social interactions in learning. We take up a position in this study which is based on both psychological and social constructivist learning principles and define creative constructivism. In this, the learner builds knowledge structures on the existing ones in different contexts or domains and is capable of moving efficiently and discriminately between them through a conceptual lens system . The importance of education lies in developing this conceptual lens system in our students. The main challenge (Caravita, 2001) is how to design and actualize the learning environments that afford a range of conditions suitable for this to happen. These ideas are the basis of a creative learning cycle advocated and studied here.

A learning cycle was first developed by Karplus (Karplus,1977) based on Piaget constructivist learning principles. The cycle described in this study differs from the Karplus cycle in the path taken and to meet the objective of conceptual understanding and transfer. This cycle consists of 3 phases. In the first phase which is exploration phase, the individual student answers initiating questions about the concepts to be learnt, then these are discussed in separate groups and lastly in the whole class. In the second phase which is elaboration phase , the

students are engaged in activities where the significant and hidden aspects of the concepts are visited for deep conceptual understanding in different contexts. The third phase of transformation phase involves the students in designing activities in novel situations for conceptual transfer from school to out-of-school contexts. These activities are designed to develop various reasoning skills via dialogic, scientific logic, analogic, 'technologic', etc through students' construction sheets which also act for formative assessment. Immediate feed-back is obtained through these for verification there and then with the help of technological aids.

This learning cycle is tried out in schools of Delhi and surrounding region through structured print material and an experimental kit on a topic of electrochemistry in class XI. The experimental try out was based on comparison of the students performance of students in experimental and control groups. The post-test only control group design is used to control the source of confounding. Achievement tests namely, chemistry, physics and physics and chemistry combined are conducted to measure the achievement of the students. The questions are posed to extract the reasoning and decision making skills of the students through experimentation and relating the isolated knowledge. Formative assessment is also done through construction sheets. Students perceptions through surveys and

interviews are also forming part of the evaluation of the effectiveness of the approach.

The report lists the results of the study in details. The study shows that the students' motivation , interest and task involvement increase in the experimental group in addition to conceptual understanding and transfer through this learning cycle. The study further shows that the mere group discussion in the exploration phase is not the only activity instrumental in understanding ,though it is found to be one of the important components of the phase but the activities in elaboration and transformation phases are found to be necessary for deep conceptual understanding and transfer. Learning conditions of explicit structure, external guidance and immediate feed-back are also found to help in meaningful learning.

The report includes the details of various tools used in this study in the form of appendices.

II. THEORETICAL CONSIDERATIONS

2.1 CONSTRUCTIVIST LEARNING PERSPECTIVES

According to Piaget (Piaget, 1971; also Nurrenberg, 2001), a learner organizes knowledge structures depending on his/her range of experiences through assimilation and accommodation. New knowledge is constructed by the learner through equilibration between the above. Potential for growth depends on the perturbation of this balanced state. For growth, (s)he must experience the event and depending upon the perturbation whether it is worthwhile to change or not, (s)he would affect the change. These ideas were the basis of 'constructivist' teaching (Fosnot, 1989 among others) in which it was emphasized that learner constructs knowledge depending on his/her prior knowledge after resolution of cognitive conflict on accommodation leading to conceptual change and also formed the basis of what is known as learning cycle (Karplus, 1977). The first phase of this learning cycle is experiencing the concept to be learnt to raise questions that cannot be assimilated in terms of past ways of thinking and the dissatisfaction is generated which causes the restructuring of the schema in the second phase on accommodation when discrepancy is resolved. Further organization of the concept takes place in third phase to expand the meaning in a new context. So, engaging the students in a quest for knowledge to develop

their rational power to think through this learning cycle and refine the everyday knowledge formed by observation of natural world was among purposes of science education. This movement came to be known as conceptual change approach. There have been many instructional models based on the above, for example, Posner et al. (1982) ; Pines and West (1986) ; Driver et al. (1986); Renner and Marek (1990); among others and supported by much research (Colburn and Clough (1997); Hewson and Hewson (1984); Roth (1984); Zollman and other cited websites among others. Special issue of "Learning and Instruction" (vol..II, no.4-5,2001) devoted to conceptual change has been published recently. We find in them the following common ground in view of science learning as a conceptual change (Gil et al. 1994):

- An exploration phase of student's prior knowledge making them explain their ideas and presenting them with events which change their ideas introducing cognitive conflict and explore the concept experimentally in as much detail as they can and relate to other experiences. The students interpret the results according to the plausibility and fruitfulness of the new ideas.
- A re-structuring phase in which the students are introduced to the concepts in a way to expose them to statements of concepts and principles through scientific language. Teacher help them in

interpretations of what they have found in exploration. Teacher provides them language and symbols for the newly acquired concept.

- The third phase provides the students further experiences with the concept to expand its meaning through application of newly learnt concepts to new situations.

The above learning cycle, however, does not take other factors into account on which the conceptual change is shown to depend . Information processing theories of cognitive development attributed the conceptual change due to the increased availability of selective attention which makes addition or deletion of the memory frameworks or representations in LTM and strengthens or weakens the connections in these frameworks (Leahey and Harris,1993,page 431). These ideas were applied to cognitive development by Vosniadou and Brewer (1987) following Carey(1985).They say that limitations in experiences and in logical thinking cannot fully explain the phenomenon of conceptual change and not being able to use it spontaneously in daily life problem solving(Resnick,1983).They attribute the formation of 'alternate' conceptions .or naive theories as these were called due to coherent explanatory framework or theory base based on students' everyday experience and these are strengthened by years of confirmation. As such these are difficult to change, because they are comfortable with these. We need learning as a process of understanding of scientific

interpretive frameworks which would interpret current understanding and compare it with reality to change them. Tyson et al (1997) suggest composition of multidimensional framework for considering conceptual change in classrooms through three conceptual lenses(i) ontological perspectives i.e. how students view nature of things in the outside world, how they look from within to outside ,thought as part of reality,(ii) epistemological perspectives i.e. how they view their own knowledge to support their belief, looking inward to interpret/judge knowledge, reality as part of thinking and (iii) social/affective perspectives .

Other mechanism through which learning takes place is believed to be through social interactions (Vygotsky, 1978). Vygotsky's theory suggests that we learn first through person-to-person interactions (interpsychological plane) and then individually through an internalisation process (intrapsychological plane) that leads to 'deep' understanding. This belief of social learning suggests an interactive group discussion learning and is reflected in the way scientists work which may throw some light on the ways to improve science learning through dialogical thinking which is a process of dialogical interactions of ideas instead of isolated mental activity through internalizing the hidden dialogical thinking after being exposed to interpersonal dialogical forms. Hogan et al (2001) show that scientists acquired their cognitive tools of developing their epistemological criteria of empirical consistency through sociocultural context of scientific working.

Recent advances in neurosciences provide evidence that the knowledge bases in different modules of the brain are also linked by parallel linking. It may be so that the conceptual restructuring may not be the only way. Moreover, it may be difficult to restructure the knowledge once firm connections have been made(Solomon , 2000). Therefore, more than one parallel link can be formed so that school or 'scientific' knowledge and out-of-school or private knowledge may co-exist and students use them when the context or situation demands(Solomon ,1983). She says that children draw their everyday knowledge from different contexts like home, peer group, school, etc. and thus child's life-world knowledge is drawn from different ways of reasoning in contrast to that of scientists According to her, deepest levels of understanding are achieved by the fluency and discrimination with which a child learns to move between the two contrasting domains of knowledge. So, there is a need to address this difference and to develop greater repertoire of ideas about the physical and cultural world through discovering new ways of conceptualizing to move between contexts e.g. school context and out-of-school context (Caravita et al, 1994). This type of 'cognitive mobility' as also suggested by Solomon(2000) is very important for deepest level of understanding and its spontaneous use in successful crossing over and back from one context (domain) to another which may be considered as hallmark of creative constructivism . It is the entwined process of knowledge construction and linking, and represents the cognitive

mobility and flexibility of dynamic linking of inter-domain and intra-domain knowledge. This can be exemplified further by considering Bateson(1980) explained by Goswami(1988) who says lower level learning, Learning I as he called, is learning within a given, fixed context, for example, conditioned or rote learning. The capacity to shift the context of Learning I is higher level learning, the shift of context, learning to learn ,is Learning II . Level II is creative learning. Shifting the context we mean as said by Goswami, for example, consider the word ass in these sentences:

The ass is an animal.

Anyone who doesn't appreciate the concept of logic is an ass.

Valsiner and Leung (1994) have also considered individual-socioecological frame of reference in which they emphasize on the ways in which a person act in the process of knowledge construction. They say that transformation of the knowledge structure is constrained, but not determined by the person-environment relationship. Some possible transformations may include addition, reorganization, splitting, merging, and their combinations. So there are number of possibilities of the transformations . At each stage of a knowledge construction, interpersonal interactions provides suggestions for transformation, but the ways in which the input is utilized by the person depends upon his cognitive capacity. The person can actively block many of the suggestions

not to alter the structure, not to link with the structure or modify the structure to construct novelty.

From the foregoing views from different perspectives, we can say that the design of classroom experiences for science learning needs an eclectic approach rather than basing these on a single learning mechanism . Learning has been viewed not an individual idiosyncratic affair but has been thought to draw on realities and socio-cultural contexts too. It is not merely replacing the old concepts with the new ones, but may also be thought of adding new knowledge and a process of creative thinking which imparts the students the capacity of dialogical thinking , capacity of scientific reasoning and analogical reasoning. This way of thinking and its active use through internalization in the intrapsychological plane from interpsychological plane depends on the learning approach emphasized in this study . The likelihood of deep understanding and its transfer seems to increase proportional to wider varieties of cognitive tools or ways of reasoning for judging of evidences . and use of proximal examples. What are the various cognitive tools that are instrumental in deep understanding and its transfer?

One cognitive tool that need to be developed is deductive–inductive type for scientific explanation and prediction, enabling to make decisions about validity of relationships between pieces of information through

falsification or confirmation as advocated in the learning cycle described earlier. A second type of cognitive tool in the form of dialogical thinking. Analogical tool(Duit, 2001) to facilitate to move efficiently between domains is amply demonstrated. People who think more about potential application in new contexts may learn more efficiently. Consideration of the relationship between science education and technology education suggests an additional cognitive tool. In solving a technological problem, knowledge may have to be drawn from different areas of science disciplines at different levels of abstraction and then synthesized. This involves creating new concepts which are more appropriate than the science ones. These have been called technological concepts (Harrison et al 1983 ;Layton, 1993). One such concept is efficiency which is being studied here. Since science progresses by simplification of complex real-life situations and separation of general principles, laws, etc from particular experience (reductionism or decontextualization as it may also be called) and then solving technological problems necessitates building back into the situation all complications of real life reversing the process of reductionism by recontextualization of knowledge i.e. reconstruction of scientific knowledge in order to achieve its articulation with practical action in technological tasks (Layton, 1993). One of the particular technological tasks which can be adopted is design and development . Design learning could bring different concepts in order to deliver value, for example efficiency as mentioned earlier. So, bringing these types of

technological laboratory activities into science learning may help in both understanding science concepts and transfer.

Study of scientific ideas in their original context i.e. historical context of discovery would also help to develop in students the conceptual understanding. It would avoid weak evidence. It highlights the thinking then and now, bringing into a sharper focus the nature and reasons for preferring one view to another of our current conceptions. It would emphasize reasoning rather than the actual argument. Thinking and actualization of a concept through scientific logic or analogic cognitive tools in new situations which can reveal the significant aspects of the concept which generally remain hidden in one situation (for example "learning to see" in new ways e.g. 'seeing the salt as dissolving', not just disappearing that it could be recovered from the interstices of liquid, 'seeing' the ions migrating in electrochemical process which is to look for at each electrode which determines the electrode potential and not the metal alone which many students take it granted, modeling electrode potential difference, etc) can help understand the hidden aspects of concepts. The transfer of this thinking could be spontaneous when practiced in altogether novel contexts. Efficiency in a technological task through design and development may be a new way of putting together well known things and may help in transfer. This technological concept must also stress that point of view of usefulness in terms of how

well it would help to cope with issues like economics, environmental, social , appropriate to local conditions (Layton, 1993).

The neuro-cognitive perspective of learning also suggests that the aforementioned activities inculcating different reasoning abilities among students constituting enriched multimodal and diverse learning contexts help in efficient learning which is elaborated below:

1.Neurocognitive Perspective:

Exciting experiments on learning and physiology of brain during the last 10 years or so have revealed important connection between the two(Martinez and Kesner, 1998). Learning is shown to be a property of brain and circuits inside it (Anderson, 1997). One of the most important parts of the brain is Central Nervous System (CNS). This is believed to be arranged in modular units, each unit has a specific function. For example, the occipital lobes mediate vision, temporal lobes process sound, frontal lobes regulate and integrate higher order cognition such as setting goals, planning behavior, maintaining a systematic approach to tasks. Different parts of the brain are reciprocally connected by nerve tracts and are stabilized by forward directed and feed-back control mechanisms .

All brains consist of individual cellular elements, called neurons. Most neurons have the same parts, a dendritic tree, cell body, axons,

synaptic buttons. They communicate with each other at synaptic space via neurotransmitters and neuromodulators stabilized through internal checks and balances. In human brains, billions of neurons interact in vast networks via even more billion of synapses. A single neuron is unlikely to encode a specific memory. Neural network might store information that memories are represented by reverberating assembly of neurons. There is, however, not one simple mechanism reported for learning and memory. There may be a set of cellular mechanisms.

At present, the most consistently reported effort of various experiences is upon the number and presumably the changes in the pattern (spatial arrangement of neurons and organization of interconnections is a pattern) and the strength of synaptic connections (Black et al(1998) in Martinez and Kesner, 1998). The pattern of these synaptic connections in the neural networks of modular units increases the probability that on future occasions or during new learning, activation of one part of these activates the rest of it, leading to recall of the information it represents. These patterns of synapses store information not only representational (type of stored memory), but also operational, dynamically influencing what is perceived and how new information is organized for inclusion within the network and deciding about 'logical operations' available to be used in constructing new meanings. Thus , knowledge is built by a dynamic process of linking or integrating new information with pre-existing neural network. It is not simply encoding information, work

must be done to reorganize the arrangement of interconnections among neurons in a network(Anderson,1997). This can be done efficiently if the new information can be contextually bound to the network assemblies already in existence. Meaningful learning or understanding thus involves existing schemata of neural activity to reconstruct networks and link newly acquired information with network of pre-existing knowledge. These networks may be neurocognitive equivalents of schemata in psychology including declaration and procedural representations of experience. Active involvement of the learner with more logical operations in action maximizes activation of schemata, encourages the work of transformation and enlargement of networks for problem solving. This dynamic constructive property is illustrated by the varying capacity of individuals to visualize spatial transformation mentally of an object after it has been rotated to a new position while out of sight. We could consider now what type of experience influences the capacity of learning. There are three parameters of an experience:

a. Amount of information available in experience,
b. Quality of experience
c. Active use of the experience

Innovative environment which is full of novel ways to learn with active use with self-initiation of experience (motivation, interest, quest, etc) is a key determinant of the quality of experience. Electron microscopic studies on the effect of enriched multimodal and differential

environment/experience provide evidence that changes in both numbers of synapses and structural characterization of synapses are involved in the storage of experiential information (Black et al , 1998). The connectivity modifications observed in an enriched environment appear more related to how neural activity is processed than how much (Thalen and Smith,1994). Therefore, it seems that quality of experience scores over the amount of information available in experience. A recently proposed model (Tononi and Edelman, 1998) signifies the importance of enriched experience of increasing complexities in cognitive development in which the authors characterize mechanism of learning as a process of neural integration (may be equivalent to transformation) and differentiation through complexities (may be equivalent to elaboration) . The highly strong and parallel interactions within and among various brain areas may facilitate the integration of the activity of these spatially segregated brain areas through feed-back into a coherent neural process Thus, systematic increase in the complexity through new and diverse learning contexts of multimodal and differentiating nature which provide instant feedback is central in developing cognitive capacity (Learning Level II). In another research, Diamond and Hopson(1998), demonstrated the development of cognitive capacity as growth of dendrites in an enriched environment. From these neuroscientific researches and creative constructivist perspectives , we see that their

theoretical bases are the same as that of learner who can understand and create efficiently through active use of innovative environment.

2. A New Learning Cycle:

Development of students' abilities of learning to understand and the active use of the understanding through a wide varieties of cognitive tools viz. dia-logical, scientific logical, and 'techno-logical' reasoning is proposed.

Learning cycle based on Piaget's ideas draws support from assimilation, accommodation and organization as discussed earlier Considering the role of other factors in science learning like technology, group reasoning , meta-cognition, etc., following learning cycle is suggested incorporating the above mentioned cognitive tools. Our assumption is that 'deep' understanding of a concept is necessary for its transfer and greater is the variety of ways or forms of reasoning employed in learning a new concept, greater will be the understanding and efficiency in the use of the concept. We are proposing the following three phases in this learning cycle :

Exploration Phase:

In this initial phase, the students monitor (written explanations) their thinking through progressive meta-cognition on key questions asked by the teacher in order to link prior knowledge to new concept, first individually, then after small group discussion and finally after class discussion with teacher. This progressive meta-cognition (concept map is one effective tool, e.g. see Towbridge and Wandersee, 1998) would maximize students opportunities for making their knowledge explicit and appropriate for the new concept. In case of experimental design, this could also be pre-lab phasing where the students would make certain assumptions which need to be confirmed or falsified. There is every possibility of recognizing conflict, if any, during this initial dialogic phase

Elaboration Phase.

In this phase, the abilities of the students in scientific logic/analogic reasoning are developed along with grasping/seeing the relationship/understand the new concept. They are taken through differentiating variety of new situations/routes to understand hidden aspects/to recognize the gaps in their knowledge for understanding the concept. The students get immediate feedback along the way through

formative questions and testing their ideas not only thinking about them. These questions would allow to tread the situations of increasing complexities in wide range of real situations. The students are provided effective high-tech devices and apparatuses which can be assembled quickly sparing enough time for the students to think, analyze, interpret and discuss. The hi- tech device use would enable the students to test the validity of the assumptions then and there made in the exploration phase and subsequently during this phase also. In case of concepts where experimentation is not possible, routes through anomalous data, new ways of comparison, analogical reasoning, etc. may be taken.

Transformation Phase:

This is 'techno-logic' phase i.e. science for technology not merely science and technology or science with technology in which the students use the understanding of the new concept in more creative ways. Here the focus is for building recontextualization by engaging the students in technological tasks which would require them to manipulate more variables and different related concepts from other disciplines for understanding the 'full impact' of the new concept. The students would be able to use the understanding in altogether novel contexts integrating the understanding with every day knowledge facilitating transfer.

III. OBJECTIVES OF THE STUDY

The experimental study reported here is in an authentic classroom environment of class XI students to promote 'deep' conceptual understanding and capacity to effectively transfer this understanding to out-of-school contexts. The major objectives of the present study were to see the effect of suggested techno-lab based learning cycle. The following objectives were in focus:

- Whether the students could express, communicate and develop the atmosphere of the class and could develop and use dialogic reasoning to link their prior and background knowledge base in order to build the new concepts.
- Whether the students could develop the ability in scientific logic through experimental inquiry and develop conceptual understanding by visiting in a number of new differentiating situations and immediate feedback through hi-tech devices.
- Whether the understanding of the concept could be transferred from one context to other efficiently through techno-lab based contexts.

- Whether more students could perform better through this approach in comparison with the traditional approach.

IV. METHODOLOGY

Methodology consisted of the following steps.

A) DEBUGGING PROGRAMME AND TEACHER TRAINING

B) EXPERIMENTAL METHOD (INSTRUCTIONAL PHASE)

  a) Population and Sample

  b) Subject-matter

  c) Design of the Study.

  d) Tools, Techniques and Procedures

  e) Interviews

  f) School visits and Data collection

  g) Scoring

A) DEBUGGING PROGRAMME AND TEACHER TRAINING

In order to improve upon the experimental method (actual instructional phase), a debugging programme was conducted in two schools prior to the instructional phase. The outcomes of the debugging programme were discussed in a workshop organized for training the teachers on the constructivist approach involved in the study . The workshop also proved helpful in reformulating some questions in the pre and post-tests, training the teachers, interalia , on the value of the constructions sheets as a record of data, in the space provided for this purpose, etc.

On the method of assessing post-tests, teachers were told that the student's self-constructions, reasoning, etc. should be rewarded more than merely reproduction of facts.

Debugging programme also helped in defining the logistics of the experimental method.

B) EXPERIMENTAL METHOD

a) Population and sample

Population of the study consisted of XI science students representing different categories of schools of Delhi and Faridabad. The sample constituted 8 schools from Delhi and one from Faridabad (3

Kendriya Vidyalayas (KV), 3 Public schools, 2 Jawahar Navodaya Vidyalayas (JNV) and 1 Navyug Public School). The schools of KV and JNV were assigned by their respective administrative bodies on our request.

The total number of students who participated in the study were 144. From each school, class XI science students were divided in two groups, namely, as experimental and control groups as shown in the table1 through randomization. In schools where there were two or more sections of class XI, only one section was selected for the study in a random way by tossing a coin.

Table - 1

	Name of participating schools	**No. of participating students**
1.	K.V, Andrews Ganj, New Delhi	20
2.	K.V, Pushp Vihar, Ner Delhi	22
3.	K.V, Badarpur, New Delhi	20
4.	J.N.V, Faridabad.	22
5.	J.N.V, *Jaffer Kalan, Delhi	-
6.	Navyug Public School Laxmibai Nagar New Delhi	20
7.	Rukmani Devi Public School, Rohini New Delhi	20
8.	Guru Harikishan Public School, Tilak Nagar, New Delhi	20
9.	D.P.S, * R.K. Puram, New Delhi	-
	Total	144

* These schools Could not complete the study, hence nil students are shown.

The designation of experimental and control groups was done in a random fashion by asking each student to draw a slip one by one from a box in which half of the slips were written as experimental groups and the rest as control group.

The students of these groups were given ranks according to the marks obtained in pre-test which was administered before the implementation of the project. Further, the rank wise matching of the two groups was done and designated as matched pairs. Wherever necessary, the back ground knowledge of both the students in a matched pair was brought to same level by imparting some instructions to the students who fell behind their counterparts.

b) Subject-matter

The study was based on a topic of galvanic cells chosen from physics and chemistry disciplines which is taught separately by the respective subject teachers. The significance of the topic lies in integration of the electrochemical concepts from physics and chemistry in addition to the need for students' deep understanding of the concepts of electrode potential and the potential difference between two electrodes. The potential difference depends on a number of factors necessitating the design skill development in order to develop an effective cell. Moreover, the students often fail to understand the relative importance of competing electrode reactions which decide the potential difference and to assign the process of current carriers inside and outside the cell among others.

In chemistry, the galvanic cell is constructed using a salt-bridge which imparts a high internal resistance which make this type of construction not useful for practical application. This type of cell shows only the correct potential difference, but when current is drawn, the potential difference falls rapidly unlike in commercial cell. Students do not recognize the importance of internal resistance which need to be understood from physics point of view and need to be integrated with the chemistry subject treatment. Thus ,designing a cell which is efficient can help the students understand the concepts and help in transferring this understanding from classroom to out-of-school situations because of their use in daily life situations.

c) Design of the Study.

The basic design used in the study is experimental in nature. The sample of students selected for the study was divided into two groups in each school, namely, experimental (constructivist) and control (traditional) groups in a random fashion as given in (a).

Both the groups were subjected to two pre-tests (consisting of chemistry and physics-see appendix -1) for making the groups more equivalent on the basis of achievement in the tests. By random selection and assignment of students to different groups, an attempt was made to increase the internal validity of the results.

The 'post-test only control group design' was used to control the sources of confounding. Here the pre-test was used only for the pre-experimental equivalence of the groups and not to see the differences of scores between the two groups after the intervention.

The design used is shown below:

	Group	Pre-test	Treatment	Post -Test
A	Experimental Group (Random)	-	(X)	O_1
B.	Control Group (Random)	-	-	O_2

The difference of mean post-test scores ($O_1 - O_2$) between the two groups (experimental & control groups) is taken as a measure of true (or significant) difference by applying t-test.

d) Tools, Techniques and Procedure

i) Achievement Test

Two pre-tests one each in chemistry and physics and three post-tests one each in physics and chemistry and one physics and chemistry (combined) were constructed to measure the achievements of the students (see appendix 2). The content was taken from Electrochemistry class XI (N.C.E.R.T text book) and current electricity of class IX (N.C.E.R.T text book) for the pre-and post-tests.

The content in the tests was organized under broader themes. Questions were posed to extract the reasoning and construction of the students understanding through explicit explanations and relationship between (factual) knowledge instead of merely reproduction of facts.

Purpose of pre-tests was to make the experimental and control groups equivalent while achievements on post-tests' were used to see the difference in the learning outcomes of the two groups.

(ii) Formative Assessment (Tool Cum Procedure)

Students Construction Sheets

A guide cum record sheets were prepared for the purpose of recording data and explanation in each of the activities done by the students in the exploration and elaboration phases of the proposed learning cycle. These were also used as formative evaluation sheets. The sheets prepared were given the name of student's construction sheets. The construction sheets contained instructions to the students, specification and details of the materials used.

Construction sheets (see appendix -3) helped as data gathering instruments among other things for all the written work done in the class.

The entire experimental phase was done through a learning cycle consisting of dialogic exploration, elaboration and transformation phases.

The purpose of the dialogic exploration was to elicit the background knowledge of the students before they performed the activities. It was done at the three levels in succession starting from individual to class group discussion through small groups. At all the three levels, students were posed questions relating to their background knowledge for learning new concepts as given in constructions sheets for performing the activities. Students needed to respond to each of the questions first independently, then after interaction in the groups of 3 or

4 students and finally with the class and the teacher. Through each successive step, students ideas were supposed to be progressively refined and upgraded. The group interaction were supposed to facilitate learning and motivation. Interactions with the teacher were supposed to help them in organizing their ideas All through the exploration phase, students planned the ideas and were ready to perform the experimental activities in the next phase after hypothesizing.

In the second phase, students were provided with the required material in the form of kit (apendix-6) to perform the activities designed for the purpose They were led through the experimentation by the sub-goals listed in the construction sheets which were in the forms of questions, they needed to respond. Here, the students were provided the opportunity to experiment in new situations related to each of the sub-goals and to test immediately the prediction in each new situation to see the gaps in their understanding and to bridge the gaps through falsification or confirmation of their supposition using hi-tech device in the experimentation

Students were needed to record the readings for each sub-goals and then interpret the results so obtained. This phase was supposed to provide logic development and understanding of the concept.

In the third phase, the students were to design an experiment which would need a technological context, enhancing the capacity to understand the concept to mobilize their understanding from school context to out-of-school context.

Formative Evaluation (Tool)

For any effective learning, formative assessment plays a significant role in giving feedback for the effectiveness of the instruction.

For this reason, a necessary provision for the in-built formative assessment was made in the methodology.

Along with imparting effectiveness to the learning by feedback, it was used to extract the data of the classroom proceedings during the experimental phase for evaluation.

Formative assessment was done at the two levels, first by the teachers involved in the study and secondly by the project fellow as a participant observer. This was done for the purpose of getting an objective data from the classroom processes.

Both the evaluators assessed the progress of the class (experimental group) on the same dimensions provided in the teachers assessment sheets (see appendix- 4).

Before assessment, both teacher and observer came out with a mutually agreed definition of each of the dimension to be assessed. Further, they continuously interacted with each other throughout the experimental phase in order to settle mutual differences and evolve a mutual consensus in assessment. It was decided that the assessment should be done by giving marks to the individual students on his/her performance on each of the dimension of learning and assessment.

In total, assessment was done on eight dimensions, three during exploration, three during elaboration and two during transformation phases.

The agreed definitions of the dimensions of the assessment are given as follows:

Exploration Phase

1. **Home assignments:** Students were needed to complete individual explorations through home assignments. Criteria for assessing the exploration done by the students were drawn from the four questions posed in this phase. (see construction sheets). Assessment was done by assessing to what extent individual student knew and learnt about the purpose of use of each of the material provided for the activity, expected observations, setting of apparatus, method or procedure and predictions, etc.

2. **Group Work**: The same criteria were laid down for assessing the individual student's understanding while interacting in the group and class discussion with teacher.

3. **Self-Motivation and Interest**: The level of self-motivation and interest of each student at the beginning and its further development through the progress of the exploration phase was assessed. It was made a point for assessment as how by benefiting from the feedback and encouragement's given by fellow students and teachers, the level of motivation of students increases in doing the activities.

Elaboration Phase

1. **Self-initiation**: To what extent students feel confident in carrying out experimentation? How do they proceed? What help do they take from teacher and one another?. How do they gather the resources and information, and organize it for the use in the experimentation. All are considered to be the characteristics of self-initiation.

2. **Experimental Skills:** Skills, techniques and knowledge which the student has for conducting experiments. Whether(s)he knows what (s)he wants to observe, etc. were also considered.

3. **Interpretations**: The way of interpretation of the observations/proceedings of the experiments, using the results in confirming or falsifying his/her hypothetical ideas or in resolving the conflicting ideas, taking help form the other fellow students and teacher in explaining and elaborating the concept in new situation, relating the results for deep understanding the concept.

Transformation

1. **Experimentation in technological context** : To what extent (s)he is able to apply the skills, techniques and knowledge of experimentation and understanding in novel technological context through design learning.

2. **Interpretation/ Transformation in Novel Context**: Can (s)he use understanding in new contexts?. To what extent (s)he relates the understanding of the concept in transferring the understanding to daily-life situations i.e. from school context to out- of -the school context.

The summative evaluation of the continuous assessment made by the teacher as well as by the observer were put in the form of marks on the space provided in the assessment sheets. Separate assessment sheets were used by the teachers and the observer for this purpose.

The assessment done by the teachers was based on their continuous interaction and observations with the students throughout the experimental phase. Observer's assessment was based on his

observation of the class for 3 days in each class. The duration of observation was from 40 minutes to one and half hour in each case on each day as per the assessment sheet (see appendix- 4).

(iii) Survey of Students' Perceptions

A tool consisting of six statements characteristics of this learning model was prepared. The purpose of the tool was to rate student's perceptions on each of the five statements and to see to what extent they had developed an appreciation of the model

A three-point rating scale was placed against each of the statements. The format of the tool is given below. The students who were subjected through the teaching and learning process based on the developed constructivist model, were asked to give their agreement, indifference and disagreement with the statements.

Format of the Tool

Name of student :

Rating Scale

School :

Class :

Statement	**Agreement (A)**	**Indifference (I)**	**Disagreement (D)**
1. Quality of the high-tech devices/ materials targeted towards solutions	A	I	D
2. Series of activities in new situations	A	I	D

helped in understanding of the concept.			
It allowed me to express my ideas and share ideas with others.	A	I	D
I felt motivated towards reflection and concept investigations.	A	I	D
I understood the concept	A	I	D
I could transfer the understanding in daily-life situations.	A	I	D

The meaning assigned to each of the statements is elaborated as ven below:

Materials/devices used took less time and gave accurate readings and helped in quick verification of results.

I was not understanding the concept. The teacher and the students helped me in eliciting my ideas and made me aware that I had alternate ideas about the concept.

Self explanatory.

I felt motivated towards reflection and the concept investigation. Emphasis was placed on the self-initiation and construction of the student's ideas about the concept. Further, along with the richness of activities, the materials and devices gave instantaneous and accurate readings which had motivational effect on me towards the reflection and understanding of concepts.

I learned the concepts meaningfully in doing the activities in new situations.

6. I could transfer the understanding in technological tasks, such as designing an efficient galvanic cell.

At the end of the experimental phase, students of experimental group along with the participant teachers were invited in a class room. First, students were told about the purpose of (gathering) and were requested to respond to each of the above six statements by rating them. The format of the tool was put on the black-board and the meaning of each of the statement was elaborated in the class. Then students were asked to make their responses on the response sheets, provided to them for the purpose. Wherever needed, individual students were helped by teachers, fellow students and the project fellow in grasping the meaning of each of the statements.

e) Interviews

Interviews were conducted immediately after the study to elicit the student's understanding and their ability to transfer this understanding to out-of school context involving daily-life situations. Four students from each school, two each from the experimental and control groups, were interviewed. The interviews were recorded on a tape-recorder and analyzed later.

f) School Visits and Data Collection:

Regular contacts were established with the schools through telephone and personal visits made by the project fellow and the investigator from the beginning ~~to~~ the end of the study. Due to heavy schedule of the schools own programmes, the period of the study got extended from expected one month to four months.

Teachers found it hard to manage time for the experimental phase. The reasons given were the rigidity of schools programmes and heavy workload on the teachers. The problems felt by teachers were sorted out by working with them and the school administration in this direction. Most of the students and teachers faced difficulties in:-

(i) Carrying out the design and development of effective galvanic cell after considering various variables to be controlled.
(ii) Understanding of theoretical and practical know-how of this model. Demonstrations in the beginning classes helped, though teachers were trained before the start of experimental phase during workshops.
(iii) Study of the students in other subjects (Math, English) who participated in the study, was affected. The co-operation from the teachers of these subjects was also sought.

The data on formative assessments, pre-tests, post-tests and assessment sheets were collected through the teachers from the schools by the project fellow. The formative assessment through observation schedule and the student's perceptions were also collected by the project fellow.

Finally, data through interviews on the learning achievement was collected by the investigator himself by conducting interviews in these schools.

g) Scoring

The formative assessment was done by the teachers and the project fellow individually by awarding marks to the students on each dimension of the assessment (see appindix-4).

Before assessment, the teachers and the project fellow (as observer) developed a mutual understanding on each of the dimensions and thereby on the assessment. Maximum of 5 marks were allotted for each aspect. The average marks obtained by the class on each of the dimensions were calculated by both the teachers and project fellow on their separate assessment sheets.

For scoring in pre and post-tests, the maximum marks were indicated in the right side of each of the question papers and marks for each question were also indicated. The assessment of pre-test was done in a traditional way by the teachers. While assessing the post-tests, the reasoning, elaboration, and explanation by the students were rewarded more than simple reproduction of the facts and principles.

The assessment through construction sheets and interviews was done qualitatively.

V. RESULTS AND ANALYSIS

1. Achievement Tests

SCHOOL WISE

School: J.N.V. Faridabad

Table No.2

Total no. of students in each group (N) = 11

Name of test	Exp. Group	Control group	Diff. of Means	Standard error	t- value	Significant Level=0.05
	Mean score	Mean score				
Post-test Chemistry	9.8	6.4	3.4	1.39	2.30	+ve
Post-test Physics	8.6	3.90	4.7	1.7	2.76	+ve
Post-test Combined	10.2	6.36	3.84	1.6	2.40	+ve

Note : The applied t-tests are one – tailed t-tests.

Table value of t at 0.05 level of significance = 2.20

From table No.2 it is seen that the mean scores of post-test physics, post-test chemistry and combined post-test of experimental group are significantly greater than that of the control groups as evidenced by applying t- test.

Hence, the hypothesis that the mean test scores of all the there post-test for the experimental group is significantly greater than that of control group is retained at 0.05 level of significance.

This indicates that students of experimental group who were taught by creative constructivist learning cycle performed better than those (i.e. control group) taught by traditional approach.

School: Kendriya Vidyalaya, Pushpa Vihar

Table - 3

Total no. of students in each group (N) = 11

Name of test	**Exp. Group**	**Control group**	**Diff. Of Means**	**Standard error**	**N t-score**	**Significant Level=.05**
	Mean score	**Mean Score**				
Post-test Chemistry	7.81	4.36	3.45	1.46	2.36	+ve
Post-test Physics	7.86	6.36	1.5	1.32	1.13	-ve
Post-test Combined	9.18	4.68	4.5	1.18	3.81	+ve

Table value of t at 0.05 level of significance = 2.20

The mean difference in the chemistry post-test and combined post-test scores of experimental and control groups came out to be 3.45 and 4.5 respectively as shown in the table 3, for which the observed 't'-values are 2.42 and 3.81 respectively.

Observed 't'-value 2.42 and 3.81 came out to be greater than the table values of 2.20.

In physics post-test, the mean score of the experimental group exceeds the mean score of control group by 1.5. The observed 't'-value (1.13) is lower than the table value of 2.20. Therefore, the hypothesis

that mean post test score of experimental group is significantly higher than the mean post test score of control group, is accepted for the chemistry and combined post-test. While the same hypothesis is rejected for the physics post-test, at .05 level of significance.

It means that learning through the Proposed model is better than the traditional approach in chemistry.

School: Kendriya Vidyalaya, Badarpur

Table - 4

Total no. of students in each group (N) = 10

Name of test	**Exp. Group**	**Control group**	**Diff. Of means**	**Standard error**	**t-value**	**Significant Level=.05**
	Mean score	**Mean score**				
Post-test Chemistry	11.45	5.95	5.5	2.24	2.45	+ve
Post-test Physics	9.85	4.40	5.45	2.11	2.58	+ve
Post-test Combine	8.1	4.85	3.25	1.29	2.51	+ve

Table value of t at 0.05 level of significance = 2.23

From the table No.4, it is clear that the difference in mean scores of experimental and control groups for chemistry, physics and combined post-tests are 5.5, 5.45 and 3.25 respectively.

On applying the t-test, observed values of 't' are found to be 2.45, 2.58 and 2.51 respectively, which are greater than their corresponding table values of 2.23. Therefore, the hypothesis that there is significant difference between the mean scores of experimental and

control groups for all the three post tests is accepted at .05 level of significance.

It implies that the proposed learning model proves to be better in understanding and transfer of understanding than that in traditional approach.

School: Kendriya Vidyalaya, Andrewsganj

Table -5

Total no. of students in each group (N) = 10

Name of test	**Exp. Group**	**Control group**	**Diff. of Means**	**Standard error**	**t-value**	**Significant Level=.05**
	Mean score	**Mean score**				
Post-test Chemistry	11.0	5.3	5.7	2.17	2.62	+ve
Post-test Physics	7.15	3.25	3.9	1.35	2.88	+ve
Post-test Combined	10.6	6.7	3.9	1.8	2.16	-ve

Table value of t at0.05 level of significance = 2.23

From the table shown above, it is clear that the difference in mean scores of experimental groups and control groups for chemistry, physics and combined post tests are 5.7, 3.9 and 3.9 respectively.

On applying the t-test, the observed value of 't-test' are found to be 2.62, 2.88 and 2.16 respectively. The observed 't' values at .05 level of significance are greater than their table values for chemistry and physics post tests as (i.e. 2.62, 2.88) indicated in the table.

In case of combined post-test the observed t value (2.16) is less than its table value of 2.23.

Hence, the hypothesis, the mean score of experimental group on the post test is significantly higher than the corresponding mean score of control group at .05 level of significance is accepted for chemistry and physics post tests respectively, while the same hypothesis is rejected in case of physics post- test.

School: Navyug Public School, Laxmibai Nagar

Table -6
Total no. of students in each group (N) = 10

Name of test	**Exp. group**	**Control group**	**Diff. of means**	**Standard error**	**t-value**	**Significant Level=.05**
	Mean score	**Mean score**				
Post-test Chemistry	9.3	5.4	3.9	1.39	2.80	+ve
Post-test Physics	5.9	3.3	2.6	0.98	2.65	+ve
Post-test Combined	8.3	4.8	3 5	1.53	2.29	+ve

Table value of t at 0.05 level of significance = 2.23

As shown in the table No.6, the difference of mean scores of experimental and control groups for the three post tests viz. Chemistry, Physics and Combined, are : 3.9, 2.6 and 3.5 respectively.

On applying the 't' test, the observed values of the three post tests viz, the chemistry, physics and the combined are found to be as 2.8, 2.65 and 2.29 respectively which are greater than their corresponding table values of 2.23.

Therefore, it is proved that the mean scores of experimental groups for all the three post-tests are significantly higher than the corresponding values of control groups at .05 level of significance.

R. D. Public School, Pitampura

Table - 7
Total no. of students in each group (N) = 10

Name of test	Exp. group	Control Group	Diff. of means	Standard error	t-value	Significant Level=.05
	Mean score	Mean score				
Post-test Chemistry	9.64	6 35	3.29	1.83	1.79	-ve
Post-test Physics	8.85	5.0	3.85	2.11	1.82	-ve
Post-test Combined	8.85	6.14	2.71	1.52	1.78	-ve

Table value of t at-0.05 level of significance = 2.23

The difference in the mean scores of experimental and control group for the three post tests i.e. chemistry, physics and combined are 3.29, 3.85 and 2.71 respectively.

On applying the 't' test, the observed values are found as 1.79, 1.82 and 1.78 respectively, which are less than their corresponding table values of 2.23 at .05 level of significance.

This means that the difference in the mean scores of experimental group and control group for all the three post-tests can be attributed to the chance/ other factors. It may be mentioned that this school

participated in debugging programme earlier and did the experimental phase in a hurry.

Therefore, the hypothesis that mean scores of experimental group is significantly higher than that of the control group is rejected for all the three post tests, at .05 level of significance.

School: Guru Harikishan Public School, Tilak Nagar

Table - 8

Total no. of students in each group (N) = 10

Name of test	**Exp. group**	**Control Group**	**Diff. Of means**	**Standard error**	**t-value**	**Significant Level=.05**
	Mean score	**Mean score**				
Post-test Chemistry	11.72	9.35	2.37	1.00	2.37	+ve
Post-test Physics	9.63	3.95	5.68	2.09	2.71	+ve
Post-test Combined	10.60	6.27	4.33	1.77	2.44	+ve

Table value of t at 0.05 level of significance = 2.23

The above table No.8, reveals that the observed difference of mean scores of experimental and control groups for the three post tests - chemistry, physics and combined are 2.37, 5.675 and 4.33 respectively.

The table value for the corresponding differences are 2.37, 2.71 & 2.44 respectively at .05 level of significance. As their observed values exceeds the table values of 2.23, it can be inferred that the hypothesis that the mean scores of experimental group for the post test of

chemistry, physics and combined are significantly higher than that of control group is accepted.

Results of All the schools taken together

Table - 9 A

Total no. of students in each group (N) = 72

Name of test	**Exp. group**	**Control group**	**Diff. Of means**	**Standard error**	**t-value**	**Significant Level=0.01**
	Mean score	**Mean score**				
Post-test Chemistry	10.08	6.14	3.94	0.62	6.35	+ve
Post-test Physics	8.35	4.48	3.87	0.6	6.45	+ve
Post-test Combined	8.96	5.91	3.05	0.52	5.86	+ve

Table value of t at 0.01 level of significance = 2.00

It is revealed in the table 9a, that the mean scores of experimental [illegible], namely - chemistry, physics and combined respectively, are higher than the corresponding mean scores of the control group by 3.94, 3.87, and 3.05 respectively.

On applying the 't' test the observed values of 't' are found to be 6.35, 6.45, 5.86 respectively, which are clearly greater than their corresponding table values of 2.00 at 0.01 level of significance for the sample size of 72. Hence, the hypothesis that the mean scores of experimental group is significantly higher than the mean scores of control group at the 0.01 level of significance is accepted for all the three post tests i.e. chemistry, physics and combined test.

Therefore, it can be inferred that the proposed model of learning is significantly better than teaching through the traditional approach.

1) On applying t-test, the mean chemistry post-test score of experimental group was found to be significantly greater than the mean chemistry post test score of control group in 6 out of 7 schools at 0.05 level of significance.

2) On applying t-test, the mean physics post-score of experimental group was found to be significantly greater than the mean physics post test score of control group in 5 out of 7 schools at 0.05 level of significance.

3) On applying t-test, the mean combined post-test score of experimental group was found to be significantly greater than the mean combined post-test score of control group in 5 out of 7 schools at 0.05 level of significance.

[illegible] mance of the students in experimental and control groups with regard to their numbers who scored higher in the two groups.

Table 9b shows the comparison of experimental and control groups in terms of relative number of students in the three tests. It shows that higher percentage of students performed better in experimental group than in control group.

TABLE - 9b

Comparison of performance of experimental and control groups in physics, chemistry and physics and chemistry combined post-tests

Post-test	**Marks obtained %**	**Control group (Students %)**	**Experimental group (Students %)**
Physics	70 55 30	0 30 70	34 60 6
Chemistry	70 55 30	10 50 40	57 31 12
Physics and Chemistry Combined	70 55 30	0 50 50	30 50 20

2. Formative assessment:

In order to impart effectiveness to the treatment, formative assessment was made a necessary condition drawn from this model . Giving feedback to the student consistently throughout the

experimentation gave the students the required confidence and direction for the meaningful learning.

So to make it more effective and objective, the two evaluators, the teachers involved in the experimentation and the project fellow associated with it, were asked to do the assessment work. The average marks awarded to the whole class participating in the experimentation by both the evaluators on the mentioned dimensions are listed in the tables.

The reliability of the assessment is seen by finding the reliability coefficient between the marks awarded by the teachers and project fellow as observer. The analysis of the formative assessment is done school wise and finally the overall assessment is done by making similar table by averaging the marks of all the students in all schools. The formative assessment was done only in five schools.

Table No. 10: School: J.N.V., Faridabad

Total no. of students in each group (N)=11

S. No.	**Dimension of Assessment**	**Teacher's assessment (Max. Marks 5)**	**Observer's assessment (Max. Marks 5)**
		Mean Score	**Mean Score**
1.	Exploration (Independently, with group, with class and teacher)	2.59	2.64
2.	Exploration (Home assignment)	2.72	2.59
3.	Exploration (Motivation, Self-	2.5	2.55

	Initiation)		
4.	Elaboration, (Self-initiation, group work)	2.54	2.59
5.	Interpretation (written & Oral)	2.45	2.41
6.	Transformation (written & Oral)	2.32	2.36

Coefficient of correlation (r = 0.61)
by Pearson product method

As clear from the table, the reliability coefficient between the awarded marks of teachers and the project fellow is r = 0.61.

Therefore, it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

Table No. 11 : School: Kendriya Vidyalaya, Pushpa Vihar

Total no. of students in each group (N) = 11

S. No.	Dimension of Assessment	Teacher's assessment (Max. Marks 5)	Observer's assessment (Max. Marks 5)
		Mean Score	Mean Score
1.	Exploration (Independently, with group with class and teacher)	2.75	2 77
2.	Exploration (Home assignment)	2.70	2.64
3.	Exploration (Motivation, Self-Initiation)	3.30	2.59
4	Elaboration, (Self-initiation, group work)	3.56	3.00
5.	Interpretation (written & Oral)	2.50	2.59
6.	Transformation (written & Oral)	2.55	2.68

Coefficient of correlation (r = .61)
by Pearson product method

As clear from the table the reliability coefficient between the awarded marks of teachers and the project fellow is r = .61.

Therefore it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

Table No.12: School: Kendriya Vidyalaya, Badarpur

Total no. of students in each group(N)= 11

S. No.	**Dimension of Assessment**	**Teacher's assessment (Max. Marks 5)**	**Observer's assessment (Max. Marks 5)**
		Mean Score	**Mean Score**
1.	Exploration (Independently, with group and with class teacher)	3.0	2.85
2.	Exploration (Home assignment)	2.8	2.70
3.	Exploration (Motivation, Self –Initiation)	3.0	2.90
4.	Elaboration, (Self-initiation, group work)	3.05	3.05
5.	Interpretation (written & Oral)	3.20	3.15
6.	Transformation (written & Oral)	2.85	2.75

Coefficient of correlation (r = .63)
by Pearson product method

As clear from the table the reliability coefficient between the awarded marks of teachers and the project fellow is r = .63.

Therefore it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

Table No.13: School: Kendriya Vidyalaya, Andrewsganj

Total no. of students in each group(N)= 10

S. No.	Dimension of Assessment	Teacher's assessment (Max. Marks 5)	Observer's assessment (Max. Marks 5)
		Mean Score	Mean Score
1.	Exploration (Independently, with group and with class teacher)	2.9	2.45
2.	Exploration (Home assignment)	3.0	2.90
3.	Exploration (Motivation, Self Initiation)	3.2	3.15
4.	Elaboration, (Self-initiation, group work)	3.1	3.00
5.	Interpretation (written & Oral)	3.15	3.20
6.	Transformation (written & Oral)	2.80	2.90

Coefficient of correlation (r = .829)
by Pearson product method

As clear from the table the reliability coefficient between the awarded marks of teachers and the project fellow is r = .829.

Therefore it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

Table No.14: School: Navyug Public School, Laxamibai Nagar

Total no. of students in each group(N)= 10

S. No.	**Dimension of Assessment**	**Teacher's assessment (Max. Marks 5)**	**Observer's assessment (Max. Marks 5)**
		Mean Score	**Mean Score**
1.	Exploration (Independently, with group and with class teacher)	1.9	3.3
2.	Exploration (Home assignment)	1.7	3.5
3.	Exploration (Motivation, Self Initiation	1.8	3.1
4.	Elaboration, (Self-initiation, group work)	2.2	3.7
5.	Interpretation (written & Oral)	2.1	3.6
6	Transformation (written & Oral)	1.8	3.4

Coefficient of correlation (r = .84)
by Pearson product method

As clear from the table the reliability coefficient between the awarded marks of teachers and the project fellow is r = .84.

Therefore it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

Table No. 15 : All the school taken together

Total no. of students in each group(N)=42

S. No.	**Dimension of Assessment**	**Teacher's assessment (Max. Marks 5)**	**Observer's assessment (Max. Marks 5)**
		Mean Score	**Mean Score**
1.	Exploration (Independently, with group and with class teacher)	2.80	2.80
2.	Exploration (Home assignment)	2.80	2.70
3.	Exploration (Motivation, Self Initiation)	3.00	2.785
4.	Elaboration, (Self-initiation, group work)	3.05	2.93
5.	Interpretation (written & Oral)	2.80	2.82
6.	Transformation (written & Oral)	2.62	2.66

Coefficient of correlation (r = .74)
by Pearson product method

As clear from the table the reliability coefficient between the awarded marks of teachers and the project fellow is r = .74

Therefore it implies that both teachers and the observers are in close agreement and assessment done by them can be taken as reasonable.

3. Three Phase Creative Learning Cycle

3.1. Exploration Phase

The students were to investigate the phenomenon of conversion of chemical energy to electrical energy through electrochemical cells. They were guided by a series of activities with in - built formative assessment to understand the concept of electrode potential and its variation depending on type of electrode combination and electrolytic solution. They were asked to design experiment on the efficiency of a galvanic cell which requires control of parameters, concepts from Physics, etc. in this technological task. The learning was to be done in three phases through group discussion and experiments. Teachers oriented the students by introducing them the key features of the contents and procedures.

1. First phase was exploration which was to make the students aware of their background knowledge of content, alternative conceptions, procedural knowledge before the actual experimentation on the basis of key explanatory questions given in the construction sheets. They were asked to answer the questions first independently, then after group discussion in 4 to 5 students and finally after class discussion with teacher to see the effect of this progressive dialogic discussion. The four key questions along with the students responses are shown in figure 1 as general pattern responses

Q1. Describe the purpose/important function of each of the material provided for activities.

Description of the functions of various materials provided for the activities progressively improved from description at individual level to their description after class discussion.

Q2. What hypotheses do you make from the activities which you are going to perform?

At the individual level, hypotheses made were appropriate, but after the group discussion, confusion started. They were not able to distinguish between electron flow and current flow. They identified electron flow as current flow. They emphasized the current rather than E.M.F. It shows that the use of daily-life term "current" dominated in there thinking. They were not able to assign the prime property of the cells i.e. Potential difference. But this thinking was slightly improved when discussing 2nd activity which is a differentiating activity in meaning-making activity of the concept, but current notion still persisted. In the fourth activity, the discussion of the main focus of the activity improves after class discussion.

Q3. How would you set up the apparatus for performing the activity to test your hypotheses?

In this description, the progress improved after group discussion.

Q4. On what basis will you analyze your results and conclude?

The results show that group discussion helped the students to transfer their tendency of copying from text-book to relate to the actual demand of the task. They were able to link their ideas after the class discussion. For example, in activity 2, they talked of standard hydrogen electrode in individual description, but after the group discussion, hydrogen is replaced by Pb electrode, as the situation demanded.

The results point out that discussion helped the students to understand the task better, but some conceptual confusion still persisted. The dialogic environment is helping the student from 'fixed type to "task involvement type". The dialogic discussion also helped the students share knowledge to improve their thinking.

Figure: 1

Answers to key questions in exploration phase

Q.1. Describe the purpose/important function of each of the material provided for the activities.

S. No.	Materials Used	Individual Exploration	Group Exploration	Exploration with Class and Teacher
1.	Resistance	Prevent electrons cloud at the electrode	Use for varying resistances and thus affect current flow	Use to get varying current(I) & Voltage (V).
2.	Agar-Agar	Acts as a contact between KNO_3 and electrode solution	Acts as a contact between KNO_3 and electrode solution	Bridge for passing electrons & ions from Zn/Zn^{2+} to Cu/Cu^{2+} through KNO_3.
3	Metal salt-solution	Flow of charges is completed by movement of ions	At the interface of metallic electrode & its solution oxidation & reduction will take place	Pressure of ions from the solution on to the metalic/electrode solution results in the oxidation and reduction, hence flow of current.
4.	Saturated KNO_3	Provides Medium	Provides medium for passing ions	Keeps the neutrality of electrode solutions.
5.	Metallic electrodes	Electrodes provide the way for transfer of electrons	Acts as (-ve) anode (Zn) & Cathode (+ve) One is rich in electrons and other deficient	Reduces with the ions and produced in the solution and helps in the flow of current.
6.	Different concentrations of solutions	Study the effect of concentration variation	Different concentration will help in producing different potentials differences	Help in producing different potential & currents.
7.	Copper vessels of different sizes	Different sizes of vessels are taken for the comparision of observations.	Different concentration will help in producing different potential differences?	Different sizes of vessels are taken for variation of surface area which may result in variation of current.
8.	Daniell Cell	Can be used as an electro chemical cell	Different concentration will help in producing different potential differences?	Is a standard electrochemical cell.
9	Multimeter	Used for taking reading/observation	Used for taking reading of I, V, & resistances	Used for taking reading of I, V, & resistances.

Q.2. What hypotheses do you make from these activities ?

Activity No.	Individual Exploration	Group Exploration	Exploration with Class and Teacher
1.	Expect electron flow from Zn/Zn^{2+} to Cu^{2+} solution undergoes oxidation & reduction reaction.	Current flow from Zn to Cu electrods.	Current will flow from Zn to Cu due to the production of electrons by redox reaction. $Zn = Zn^{++} + 2e^-$ - Oxidation $2e + Cu^{2+} = Cu$ - reduction. This can be observed by measuring current by .multimeter.
2.	Which electrode will act as anode and which as cathode in a particular type electrolytic cell from the pair of Zn,Cu, Pb,Fe and Ag.	Different combination of electro chemical cells will give different value of P D. on multimeter	Different electrochemical cell will give different value of P.D. in multimeter, when dipped in their respective solution Also the different current.
3.	P.D is proportional to concentration	P.D. or E M F will be less or more as concentration varies	E.M.F. & Current will vary i.e. may increase or decrease depending on whose concentration (Zn^{2+} or Cu^{2+}) is varied.
4.	Current decreases with increase in resistance	Current flow will decrease when internal resistance increases and increase with surface area	Current flow will decrease when internal resistance increases and increase with surface area Internal resistance is the resistance offered by the salt solutions to the flow of current (I).

Q.3. How would you setup the apparatus for performing the activity to test your hypotheses?

Activity No.	Individual Exploration	Group Exploration	Exploration with Class and Teacher
1.	Verbal discription (incomplete). Copied diagram of the apparatus from the book.	Same diagram	Diagram of the lab constructed cell
2.	x,y=Cu,Pb,Ag,Zn,Fe	Improved one-same diagram	Same diagram as above using different electrodes (Fe,Ag,Zn,Cu,Pb)
3.	x,y=Cu,Pb,Ag,Zn,Fe	Improved one-same diagram	For different combination of the electrodes.
4	Different surface areas of the vessel.	Basically same diagram	Improved

Q.4. On what basis will you analyse & conclude the results?

Activity No.	Individual Exploration	Group Exploration	Exploration with Class and Teacher
1.	How the device is set up e-flow through Zn electrode.	$Zn \rightarrow Zn^{2+} + 2e$	How much current is passed through copper & nichrome wires
2.	If one is taken as standard (reference) electrode e.g. hydrogen electrode	Standard hydrogen electrode should be used as reference electrode for combinations of electrolytic cell and then compare their E.M.F's	By taking Pb or any other electrode as reference electrode the electrode potentials for different combination can be observed.
3.	Measuring E^o, through Nernst Equation.	By Increasing the concentration of Electrolyte/CuSO4----Cu^{2+}, number of ions increase, and then they will combine with more e- to form Cu.	By changing the concentration of the electrolyte and taking the readings in multimeter.
4.	By changing area & internal resistance, taking readings.	By changing area & internal resistance, taking readings.	By changing surface area & internal resistance and comparing the readings for the different cases.

3.2. Elaboration Phase

Activity-1

In this phase, students were to act deliberately and constantly in contrast to traditional instructions.

Research activity was centered in these guided experiments to critically evaluate and validate their understanding by testing the concepts. Cultural context was set for scientific actions apart from novel academic contexts.

A newly developed way of constructing the Zn-Cu galvanic cell (in this project) was introduced to the teacher and students. **The students were involved in the construction of the cell in the school before the commencement of the activity.**

After constructing two or three galvanic cells consisting of different electrodes, students were asked some questions in the construction sheets like - naming of the electrodes, nature of reactions taking place at a particular electrode (i.e. Redox reactions) - role of agar-agar, taking the reading for the EMF of cell on the multimeter and reasons why they observed a different value, if any, from the literature value for that combination.

They were guided to do some experimentation such as connecting LED and observe the change. **Student were able to answer the questions and conduct experiments with the help of teacher and** through interacting with each other.

Throughout this activity, students came to know how to perform the experiments themselves. They got a feeling of confidence by doing this (observed through observation schedule).

Students also reported some problems in the accuracy of measuring instruments used which they sorted out with the help of teachers.

Activity-2

Constructing of galvanic cells with different combinations of electrodes (Zn, Cu, Fe, Ag, Pb) and studying their electrode potentials.

In this activity, students could construct and record the different cell potentials for all the possible combinations. Then as guided (construction sheets), they took lead (Pb) as reference electrode and recorded the electrode potentials for (Pb-Fe), Pb-Cu, Pb-Zn and Pb-Ag combinations.

They were able to know the polarities of the electrodes and explained why the sign of the electrode potential is positive for some and negative for others (correctly). Also they could write the redox reactions in ionic form.

In answering why Pb/Pb++ was taken as reference electrode, they explained that it is because the electrode potential of Pb/Pb++ is very near (0.13V) to zero electrode potential (of standard hydrogen electrode). They explained that they could understand the concept of reference electrode. They explained that besides Pb/Pb++ and standard hydrogen electrodes, any other electrode such as Zn/Zn++ can also be taken as reference electrode, if it is convenient to do so.

Further on the magnitude of electrode potential, they wrote that it depends on reactivity of the metal in relation to other.

On replacing Cu/H+ in place of Cu/Cu++ in a Zn-Cu electrode, they reported that value of electrode potential drops. The reason given for the drop, was that some bubble of H_2 gas have formed which resulted in different electrode reaction at the copper electrode, namely, $2H^{+}+2e^{-} \rightarrow H_2$ which has a zero electrode potential. By taking the students to observe P.D. in various new contexts, students were able to explain the readings indicating their complete understanding of the concept.

Activity-3

Studying the effect of concentration variation of an electrolyte on the value of electrode potential.

Students performed this activity by keeping the concentration of one of the electrolytes in Zn-Cu cell constant and varying the concentration of other electrolyte.

Here, they could record the change in E.M.F (increase or decrease depending in which electrolytes concentration was varied). In replying the question why the change took place in the value of E.M.F of the cell, they could explain it appropriately. Also students could record the slight variation in the value of E.M.F when $ZnSO_4$ was replaced by water . Here again, they could put proper explanation for it. A few of them could not relate the results to Nernst equation, however.

3.3 Transformation Phase (Technological Task)

Activity-4

Studying the effect of

(1) Surface area

(2) Internal resistance on the value of current to build an efficient cell.

Students could record the value of potential difference and current by applying an external resistance with the different types of galvanic cells (namely - Lab constructed and commercial Daniell cells). They were able to see the effect of variation of the area of one of the electrodes of the cell on the amount of current delivered from it. Their observation was that amount of current increases with the increase in the area of electrode.

Students in a separate activity recorded internal resistance by directly measuring it from the cell and also the amount of current

delivered by the cell for a particular value of internal resistance. Their observation showed that with the decrease in internal resistance, the value of current increased. This indicated that bringing more parameters into contexts of technological tasks, their reconstruction activity of designing a cell for its effective performance helped to improve the transfer of knowledge. Activities regarding the relationship between resistance, current and voltage helped the students in the above design. The experiments on related concepts in physics and chemistry helped the students to understand the concepts and they could succeed in the technological tasks based on their understanding.

In order to see the relative difference in the learning of experimental and control groups with respect to understanding and transfer of knowledge in technological tasks and also in the development of scientific attitudes, the performance of students through the construction sheets and post-tests were analyzed.

In analyzing the construction sheets and post-test (chemistry and physics) a criterion for the proper/satisfactory responses was set. If the response made by students fulfilled the criterion, then his/her answer was taken to be correct. On the other hand, if the response made was not satisfactory, then it was assumed to be incorrect.

Since combined post-test was of the objective type, there was one correct response out of four alternatives. For measuring the extent of understanding the concept and transferring the understanding in technological tasks, only essential items from the construction sheets and post-tests were taken for the analysis (i.e. items designed for this purpose).

Item 1- You are faced with a conflicting concept, what often do you do?

(from combined post-test)

	Control Group	Experimental Group
No. of students giving correct response	15	31
Total No. of Students	42	42

Note: (Correct response): Explore it by yourself, discuss with friends, teachers and try to test it.

Item 2. How would you proceed in resolving the conflict of whether a steel spoon and a wooden table may have the same or different temperatures at a moment ?

(from combined post-test)

Ratio of students giving	Control Group	Experimental Group
Correct responses	16/42	32/42

Note: (Correct response):By measuring the temperature with a thermometer.

Item. 3 Can understand and apply the concept of electrode potential in novel situations (from construction sheets)

	School-1	School-2	Total
No. of students giving correct answers	9	8	17
Total students	10	10	20

Criteria: Student understands and applies that from among the metallic electrodes such as Pb, Ag, Zn, Cu, and Fe, any one can be used as reference electrode. Also can select the one which can be suitably used for the purpose.

Item 4. Can form a hypothesis on the effect on E.M.F. of a galvanic cell on changing the nature of the electrolyte (i.e. $CuSO_4$ replaced by H_2SO_4 or H_2O) and reasons for it. (from post-test (chemistry))

Ratio of students giving correct responses	Control Group	Experimental Group
	15/42	27/42

Criteria: Student can respond that on replacing H_2SO_4 and H_2O for $CuSO_4$, there will be different electrode - electrolytic process which may result in decrease in E.M.F. and can actually test it in case of acidified H_2O.

Item 5. A Daniell cell is connected to a D.C. power source (battery) of potential V in opposition as indicated below:

$Zn(s)\,|Zn^{2+}\,(aq)|\,|Cu^{2+}\,(aq)\,|\,Cu(s)$

Give direction of current flow and cell reaction for the following:

(i) V is less than 1.10V (E.M.F. for Daniell Cell)

(ii) V is equal to 1.10V

(iii) V is greater than 1.10V

	Control Group	Experimental Group
No. of students giving correct responses	7	16
Total No. of students	42	42

Criteria: student will respond

(i) from Cu to Zn

(ii) no net flow

(iii) from Zn to Cu

Item 6: Can suggest parameters to be optimized for designing a commercial cell, delivering appreciable current.

	Control Group	Experimental Group
No. of students giving correct responses	3	11
Total no. of students	42	42

Criteria: Correct answers: Larger surface area of electrodes, higher concentration of electrolytes based of Nernst-Equation, Low internal and external resistance and larger value of electrodes potential difference, etc.

Item 7: On whose electrode potentials should the E.M.F depend when two bimetallic electrodes (Fe-Zn) and (Cu-Ag) are dipped in a standard solution of Zn/Zn2+ forming a galvanic cell, Fe-Cu, Fe-Ag, Zn-Cu or Zn-Ag ?

	Control Group	Experimental Group
Ratio of students giving correct responses	6/42	21/42

Criteria/Correct answer: Potential of the cell depends on the electrode potential values of the individual metal in a bimetallic electrode which has higher value of electrode potential (positive or negative as per case).

The above results are summarized as follows:

1) 38% of the students from control group gave correct response for taking appropriate steps in resolving the conflicting concepts while in case of the experimental group, the correct responses are 73.01%

2) 76% of students from the experimental group gave correct answers in resolving the concept of whether a steel spoon or a wooden table may have the same or different temperature as against 37.7% of correct responses of the control group.

3) 85% (17 out of 20) students who underwent the treatment could understood and apply the concept of reference electrode in novel situation.

4) 64% (27 out of 42) students who underwent the treatment could form hypothesis on the effect of E.M.F of the galvanic cell by changing the nature of electrolyte.

5) 38% (16 out of 42) students of the experimental group could respond correctly for the effect on the amount and direction of the current drawn from Zn-Cu galvanic cell, when a DC. source of E.M.F. is connected with it. The correct responses of control group for the same were 17% (7 out of 42)

6) 26% students of the experimental group could suggest parameters to be taken in constructing an efficient galvanic cell, while only 7% students of control group gave the correct responses.

7) 50% of the students of the experimental group could record the correct value of E.M.F developed in a galvanic cell formed by two bimetallic electrodes.

4. RESULTS AND ANALYSIS OF THE SURVEY OF STUDENTS' PERCEPTIONS.

(Perception tested by using x^2- test)

On six statements characteristic of our constructivist learning model, 48 students were asked to give their responses to the statements which were categorized on a rating scale as agree, indifferent or disagree.

The divergence of observed results from the expected ones was tested on the hypothesis of equal probability (i.e. Null hypothesis)

48 students were asked to respond towards each of the statement by marking Agree (A), Indifferent (I) and Disagree (D) and x^2 is found for each statement.

1. Statement 1.

Quality of the hi-tech devices and materials used was targeted towards the solutions.

Responses

	A	I	D
Observed (fo)	27	8	13
Expected (fe)	16	16	16

x^2= 12.12, df = 2, level of significance = 0.05

Table value of x^2= 5.991

From the above table, it can be inferred that the perception of the students has changed significantly as a result of undergoing teaching and learning through constructivist approach.

Statement 2.

Series of activities in new situations helped me in understanding of the concept.

Responses	A	I	D
Observed (fo)	25	8	15
Expected (fe)	16	16	16

x^2= 9.125, df = 2, level of significance = 0.05

From the above table, it can be inferred that the perception of students has changed significantly as a result of undergoing teaching and learning through constructivist approach.

Statement 3.

It allowed me to express myself and share ideas with others.

Responses	A	I	D
Observed (fo)	29	12	7
Expected (fe)	16	16	16

x^2 = 16.62 df = 2, level of significance = 0.05

From the above table, it can be inferred that the perception of students has changed significantly as a result of undergoing teaching and learning through constructivist approach.

Statement 4.

I felt motivated towards reflection and concept investigation.

Responses	A	I	II
Observed (fo)	25	13	10
Expected (fe)	16	16	16

$x^2 = 7.88$, df = 2, level of significance = 0.05

From the above table, it can be inferred that the perception of students has changed significantly as a result of undergoing teaching and learning through constructivist approach.

Statement 5.

I understood the concept

Responses	A	I	D
Observed (fo)	24	10	14
Expected (fe)	16	16	16

$x^2 = 6.5$, df = 2, level of significance = 0.05

From above table it can be inferred that the perception of students has changed significantly as a result of undergoing teaching and learning through constructivist approach.

Statement 6.

I could transfer the understanding in daily-life situations.

Responses	A	I	D
Observed (fo)	21	13	14
Expected (fe)	16	16	16

x^2= 2.00, df = 2, level of significance = 0.05

From the above table, it is inferred that the perception of the students regarding item No. 6 has not changed significantly at 0.05 level of significance.

5. Interviews

For the purpose of our research on creative constructivist learning through a learning cycle involving enriched environment, mere improvement of skills in using the experimental techniques used would have been an unsatisfactory result. Transition from this mere experimental skills acquisition state to deep understanding of the concepts and creative thinking where the students can transfer the knowledge from one domain to other domain were important for our research objectives. What are the factors which control this transition? We believe that the proposed learning cycle enabling the students to develop multiple ways of reasoning is capable of promoting this change. We have categorised this learning cycle as described earlier into three phases as follows·

1. The use of dialogic exploration phase e.g. in experimental enquiry to promote meaning acquiring from exploration of experimental details, metacognition of background knowledge for the new concept to be learnt through progressive dialogic reasoning with the help of teacher. This phase acts to facilitate to link the background knowledge to future learning.

2. The use of elaboration phase to differentiate significant aspects of the new concept through visiting a number of new situations by experimentation and verification of their thinking right there judging the results on the basis of scientific reasoning. For theoretical concepts where experimentation is difficult analogical reasoning and or 'chronological' reasoning are viewed to be effective.
3. The use of transformation phase through 'techno-logic' reasoning by the use of the concept in altogether novel context integrating the concept with other concepts.

We wanted to see that whether this learning cycle helped to promote the change from teacher dominated rote-learning to creative learning. The students were interviewed after they underwent through the above learning cycle The interviews were recorded and analysed. The transitions were indicated by the student's deep understanding of the subject matter where they could furnish the explanation and establish a relation between different pieces of isolated information and use of this understanding in unfamiliar situations. Most of the students from experimental group who were interviewed in practical situation in groups school wise liked to do the background work in an interactive way before the experimentation where they were allowed to express their knowledge, through individual and group discussion. They further

appreciated that recording in the construction sheets cleared their doubts, problems, etc. through these type of discussions.

A representative dialogue between the interviewer and a student is given below, because the responses of all the students interviewed were more or less the same. Language of the students' answers reproduced here have been refined.

Interviewer : How were you exposed to the concept of electrode potential?

Student : Through my observation of the functioning of a dry cell , key in the construction sheets and class discussion.

Interviewer : How did the class discussion help you?

Student : It gave me the 'feeling' of background knowledge for the concept. I could remove my doubts easily.

Interviewer : What did you do with the apparatus provided?

Student : I could not do very much in the beginning, but when my helped me to set up the same, I could do the experiments.

The students thought that the explanation in answering the key questions individually and also with other students helped them understand the background concepts which they never did before. However, the help of the teacher was necessary to guide them through the technical details. The students liked the experimental part very

much, specially when they could verify fast their predictions through digital multimeter . They were led through some formative questions about the concept while doing the experiments such that they would elaborate the understanding of the concept through visiting it in a number of new situations.

Interviewer : How did the experiments and the construction sheet help you in understanding the concept of electrode potential and E.M.F ?

Student : I could verify the results of my thinking then and there.

Interviewer : How did the construction sheet help you, in particular ?

Student : The questions in the construction sheet to do experiments in new situations where I could think and verify the result.

Interviewer : Did you work more than what you would otherwise do in the traditional class room?

Student : Yes, we have to explain and do it all ourselves.

Interviewer : What was learning like?

Student : It was exciting to learn and could really understand the concept.
I could see its significant aspects.

The students were exposed to more challenging technological tasks of designing a device based on the concept. Again they were led through the construction sheet via formative questions. From the designing activity which involved the application of understanding of the concept from physics and chemistry disciplines and at the same time involving daily life technological device was enough to give a lot of interest for further investigation.

Interviewer : How did the experiments from physics and chemistry together help you?

Student : These helped me in visualizing the concept use from various angles.

Interviewer : Like?

Student : The experiments on lab constructed cell and commercial cell gave me confidence to study the essential parameters for the efficiency of a cell.

Interviewer : What do you think about this way of working?

Student : I am very much curious to do a project on this.

We wanted to see whether the students actually understood the concept of electrode potential and potential difference and see that they could transfer the understanding in altogether novel situation of daily life importance.

Interviewer : Many chemical reactions take place with release of energy. How would you change this energy to electrical energy?

Student : By carrying the reaction in a galvanic cell.

Interviewer : How would you carry out?

Student : Explains the cell by taking an example of Cu/Zn cell.

Interviewer : What is the cause of potential difference?

Student : Zn dissolves as Zn^{2+} ions in the electrolyte and gives out electrons. These are at higher potential than those at the other electrode.

So, these electrons like to escape.

Interviewer : Now let us insert these two electrodes into a lemon. What would you expect?

Student : I would expect a potential difference.

Interviewer : Explain your thinking.

Student : Two reactions will take place, like $Zn\ (s) \rightarrow Zn^{2+}\ (aq) + 2e^-$ at Zn electrode and $Cu^{2+}\ (aq) + 2e^- \rightarrow Cu\ (s)$ at Cu electrode.

Interviewer : But where are the Cu^{2+} ions in lemon.

Student : Silent

Interviewer : Let us measure the potential difference.

Student : It is 0.83 V.

Interviewer : How much value of potential difference did you obtain from Zn/Cu Daniell cell?

Student : 1.1 V.

Interviewer : Why is the difference in these values, even when Zu/Cu electrodes are same.

Student : Oh! I see now. The reactions are Zn (s) → Zn^{2+} (aq) + $2e^-$ at Zn electrode and $2H^+$ (aq) + $2e^-$ → H_2 (g) at Cu electrode.

Interviewer : From where did the H^+ ions come ?

Student : From the acid in the lemon?

Interviewer : Let us measure the potential difference when we dip Zu/Cu electrodes in tap water.

What value do you expect now?

Student : I think it should give the same value as in lemon.

Interviewer : Why?

Student : Because there will also be H^+ ions reduced.

Interviewer : Measure it.

Student : Yes, I think I am right.

Interviewer : How about your this cell giving sufficient current maintaining the constant voltage difference for a while?

Student : I think it can give sufficient current.

Interviewer : Show me.

Student : Measures the internal resistance of the cell and drop in the potential difference when passing the current through a bulb.

Interviewer : Comment on your result.

Student : Its IR is more and it cannot maintain the constant potential difference.

Interviewer : Why did your commercial cell give current and maintains constant potential difference for a while.

Student : Its IR is very less.

Interviewer : How can you design an efficient cell?

Student : First of all I would reduce its IR.

The control group students were also exposed to similar types of questions. These students showed their ignorance about the conceptual understandings of electrode potential and potential difference in new situations. They could recall only isolated pieces of information regarding galvanic cells.

VI. CONCLUSIONS

Quantitative analyses (achievement tests) and qualitative analyses (construction sheets and interviews) show that the proposed learning cycle enhance

1. Students' motivation, interest and task involvement in addition to the understanding and transfer of this understanding to out-of-school contexts
2. Mere group discussion in the exploration phase is not the only activity instrumental in conceptual understanding, though it is found to be one of the important ones , but the activities in elaboration and transformation phases are found to be necessary for conceptual understanding.
3. Learning conditions of explicit structure, external guidance and immediate feedback are also found to help in meaningful learning .
4. Moreover, the study shows that more percentage of students perform better in comparison to the traditional approach.

The enhanced understanding is achieved after visiting the concept in various situations revealing significant aspects of the concept which generally remain hidden and immediate verification of the thinking. The transfer is facilitated by the use of the thinking through design and development activities in novel technological tasks. Group work,

however, generated interest, motivation and task - commitment. Proposed model put restrictions on time and content covered in a class. It is the quality of the content and approach of immediate feedback with proper guidance which were found to be the appropriate learning conditions (through construction sheets and hi-tech devices) . The following steps are suggested to improve the understanding of the concepts in science and its transfer based on the study:

- Key questions to students and explicit structure in the construction sheets.
- Progressive dialogic exploration phase.
- Elaboration phase by designing experiences in different situations revealing significant aspects of the concepts and immediate verification of the validity of the thinking.
- Transformation phase by designing technological experiences in broad-based novel contexts for transfer of the understanding to out-of-school contexts.

In case of theoretical nature of the concepts , design of learning experiences involving analogical reasoning (Harrison et al, 2000) or 'chronological' reasoning (Monk et al, 1997) providing historical contexts for interpretation in relation to present conception may be included in

the learning cycle. Concept mapping before and after learning a new concept has also been shown to facilitate connections between different pieces of information.

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Appendix – 1

Name of the School : ______________________

Name of the Student : ______________________

Class and Section : ______________________

Day and Date : ______________________

TIME : 30 MIN. **MM-20**

PRE-TEST (Chemistry)

Answer the following questions in the space provided

1 In each of the following reactions, which substance is getting oxidized and which is reduced (3)

a) Fe_2O_3 (s) + 2 Al (s) → Al_2O_3 (s) + 2 Fe (s)

b) Zn (s) + $PbCl_2$ (aq) → Pb (s) + $ZnCl_2$ (aq)

c) $8H_3O^+(aq)+MnO_4^-(aq)+5Fe^{2+}(aq)\rightarrow$

$5Fe^{3+}(aq)+Mn^{2+}(aq)+12H_2O(l)$

2 Write the electronic configuration of following elements (2)

Zn, Cu, Ca, Cr, Cl, O, P, N

3 For each of the above element, name the elements which have tendency to loose electrons and which ones to gain electrons (2)

What, if anything, would you expect to observe if you do the following

a) put a strip of Fe in $CuSO_4$ (3)

b) put a strip of Cu in $FeSO_4$

c) put a strip of Cu in $CuSO_4$

Write the chemical equations of the reactions expected, if any?

Identify the metals being reduced and oxidised.

Write the oxidation and reduction reaction separately and see what happens if you combine them in each case

When yellow iron (III) chloride solution is mixed with sodium sulphate solution, the solution changes to a pale green colour. Explain with the help of chemical reaction (2)

Explain the origin of electrode potential. What is the reason for not being ablt to measure true electrode potential of a single electrode?

What is a standard/reference electrode? Name the standard reference electrode which is used for measuring other electrode potentials. (2)

What according to you is the basis of electro-chemical cell? (2)

What type of chemical reactions needed for this cell?

8. Depict the electrochemical cell in which the reaction is

$Zn(s) + 2\,Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2\,Ag(s)$

Also a) Mark the anode and cathode (4)

b) Show movement of ions and electrons

c) Electrode reactions

d) Direction of conventional current.

Name of the School: ______________________

Name of the Student : ______________________

Class and Section : ______________________

Day and Date : ______________________

TIME : 30 MIN. **MM-20**

PRE-TEST (Physics)

Answer the following questions in the space provided .

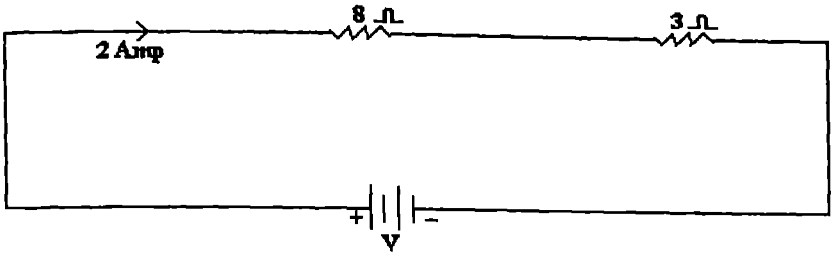
1. How will you describe electric current? (3)

2. How is the Potential difference maintained across the ends of a conductor? (3)

3. How do you differentiate between Potential difference and EMF? (2)

4. State Ohm's law and draw V-I graph? (4)

5. What is the voltage used for domestic electric circuits? Is there a potential difference between the contacts of electric switch when it is open? (2)



6. If a potential difference of V volts is applied across a conductor of length L, what is the electric field across it? Write its units. (2)

7. An Ammeter is an instrument to measure current,
   a. Should it be connected in series or parallel?
   b. Should it have a higher or low resistance? (2)

8. A voltmeter measures potential difference,
   (a) Should if de connected in series or parallel?
   (b) Should if have a higher or low resistance? (2)

Appendix – 2

Name of the School : ____________________

Name of the Student : ____________________

Class and Section : ____________________

Day and Date : ____________________

TIME : 30 MIN. **MM-20**

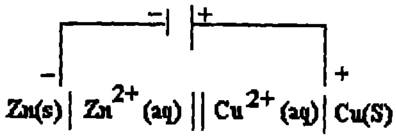
POST-TEST (Chemistry)

Answer the following questions in the space provided :

1. The movement of electrons produced in an electrochemical cell disturbs the equilibrium. Do you agree with this statement? Explain giving reasons. When does the E.M.F of the electrochemical cell attain (i) Zero value (ii) Maximum value? (2)

2. Give reason why blue colour of copper sulphate is discharged slowly when an iron rod is dipped into it. Given : $E^0\ (Cu^{2+}/Cu) = +0.34V$ and $E^0(Fe^{2+}/Fe) = -0.44V$ (1)

3. A Daniell Cell is connected to a D.C. power Source (battery) of potential V in opposition as indicated below : (3)



Give direction of current flow and cell reaction for the following :

i) V is less than 1.10 V (EMF for Daniell Cell)

ii) V is equal to 1.10 V.

iii) V is greater than 1.10 V.

4. In the above question, if Daniell cell is replaced by Zn/dil H_2SO_4/Cu cell, answer the above questions. What difference do you observe between the two cases. (3)

5. Calculate the value E^0 for each of the following reactions. Decide whether you can set up the cell in the direction written. (2)

a) $2\,I^- (aq) + Zn^{2+} (aq) \rightarrow I_2 (s) + Zn (s)$

b) $Ag (s) + Fe^{3+} (aq) \rightarrow Ag^+ (aq) + Fe^{2+} (aq)$

c) $zn^{2+} (aq) + Ni (s) \rightarrow Zn (s) + Ni^{2+} (aq)$

d) $Ce^{4+} (aq) + Cl^- (aq) \rightarrow Ce^{3+} (aq) + Cl_2(g)$

E^0 $Pt/I_2/I^-$ = + 0.535 V
E^0 Zn/Zn^{2+} = – 0.76 V
E^0 Ag/Ag^+ = + 0 80 V
E^0 Fe^{3+}/Fe^{2+} = + 0.77 V
E^0 Ni/Ni^{2+} = – 0.25 V
E^0 Ce^{4+}/Ce^{3+} = + 1.61 V
E^0 Cl_2/Cl^- = +1 36 V

6. Consider the following Half-reactions with the standard electrode potentials:

	E^0 (V)
$Ce^{4+} (aq) + e^- = Ce^{3+} (aq)$	+ 1.61
$Ag^+ (aq) + e^- = Ag (s)$	+ 0.80
$Hg^{2+} (aq) + 2\,e^- = 2\,Hg (l)$	+ 0.79
$Sn^{2+} (aq) + 2\,e^- = Sn (s)$	– 0.14
$Ni^{2+} (aq) + 2\,e^- = Ni (s)$	– 0.25
$Al^{3+} (aq) + 3\,e^- = Al (s)$	– 1.66

Answer the following questions: (4)

a) Which is the weakest oxidising agent in the list?

b) Which is the strongest oxidising agent?

c) Which is the strongest reducing agent?

d) Which is the weakest reducing agent?

e) Will Sn (s) reduce Ag^+ (aq) to Ag (s) ?

f) Will Hg (1) reduces Sn^{2+} (aq) to Sn (s)?

g) Name the ions that can be reduced by Sn (s)?

h) What metals can be oxidised by Ag^+ (aq) ?

7. If we take water in place of $ZnSO_4$ in Zn-Cu electrochemical cell, will it show the EMF? Give reasons for your answer. (2)

8. In the following cell (2)

a) $Mg(s)/Mg^{2+}(aq) \;||\; Cu^{+2}(aq)/Cu(s)$

i) If concentration of $Mg^{2+}(aq)$ is increased what will be change in E.M.F. of the cell?

ii) If the concentration of $[Cu^{+2}]$ is increased what will be change in E.M.F of the cell?

iii) Would the cell work equally good if the salt bridge is replaced by an ordinary copper wire? Explain your answer.

9. What are the parameters you would consider for designing Cu-Zn electrochemical cell which can deliver current comparable to commercial Daniell cell? (1)

Name of the School : ______________________

Name of the Student : ______________________

Class and Section : ______________________

Day and Date : ______________________

TIME : 30 MIN. **MM-20**

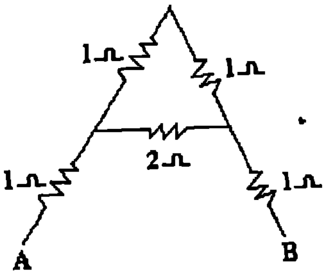
POST-TEST (Physics)

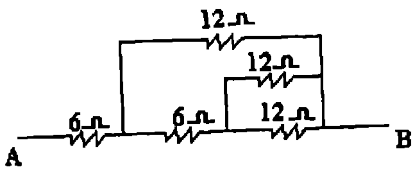
Answer the following questions in the space provided :

1. Given three resistance of values 2Ω, 3Ω and 5Ω, how will you connect them to get,
   a. Maximum resistance. (2)
   b. Minimum resistance.

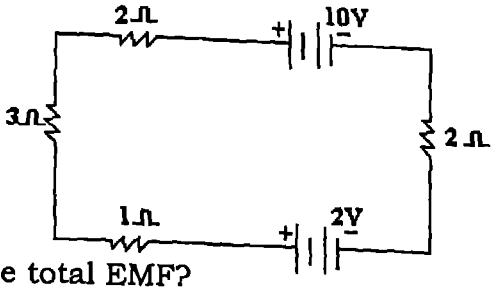
2. An equilateral triangle is formed with each side having a resistance of 1Ω. What is the effective resistance across any side? (2)

3. Find the equivalent resistance across the points A and B in the following circuits. (2)





4.



a. What is the total EMF?

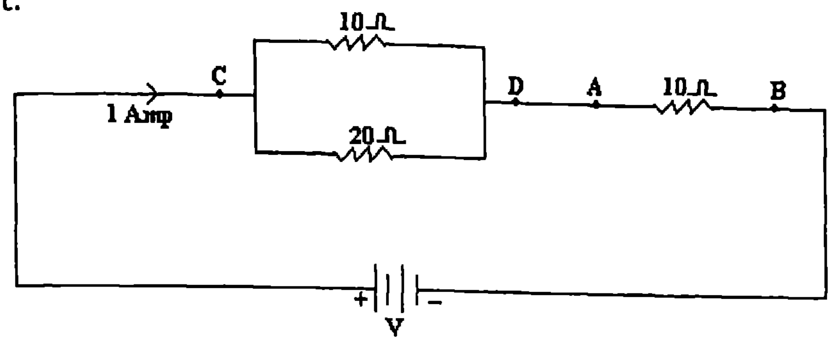
b. What is the current through the resistances? (2)

5. A wire is stretched until its length is doubled. What will be its new resistance? (2)

6. Can any material have zero resistance? Explain (2)

7. Describe with the help of a circuit diagram, how will you measure the resistance of a conductor say, in an electrochemical cell, by using a voltmeter and ammeter. Draw the diagram. Further, suggest ways to get maximum current from an electrochemical cell. (4)

8. Find the potential difference across A and B; and C and D in the following circuit. (2)



9. The following cell has E.M.F. (E^0) of 5.91V: Li / Li^+(aq) ‖ F^-(aq) / F_2(g). It is not an ideal battery for many uses. Why is it not safe to use it for consumer products. How can you get potential greater than 6V from batteries made of reasonably safe and economic materials? (2)

Name of the School : ____________________

Name of the Student : ____________________

Class and Section : ____________________

Day and Date : ____________________

TIME : 30 MIN. **MM-20**

POST-TEST (C)

Answer the following questions by marking √ against the given options:

1. In the circuit shown, V_1, V_2, V_3 and V_4 are accurate voltmeters; R is a resistance, B is a battery. Which pair of voltmeter is sure to have the same readings?

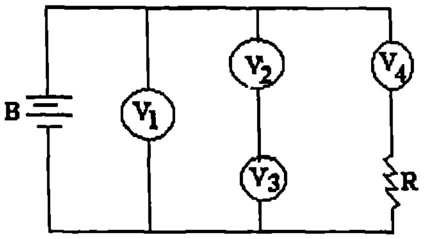
   a) V_1 and V_2

   b) V_2 and V_4

   c) V_1 and V_4

   d) V_2 and V_3

   e) None of there



2. Which of the following may be used for reasonably accurate measurement of the E.M.F of a cell?

   a) A voltmeter with low resistance

   b) A voltmeter with high resistance

   c) An ammeter with low resistance

   d) An ammeter with high resistance

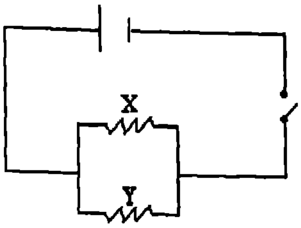
3. Two wires X and Y are connected in parallel across a battery. If their temperatures are equal, they lose heat to the surroundings at the same rate. With switch open, their resistances are equal. However, the temperature coefficient of resistivity, which determines the rate of increase of resistance with temperature is greater for wire X. If the switch is closed, which of the wire will eventually be the hotter?

a) Wire X

b) Wire Y

c) They will be equally hot

d) Data are insufficient to decide



4. A bimetallic strip of Zn and Fe is dipped in a solutions containing Zn^{++} ions at standard conditions forming one electrode system of an electrochemical cell. The other electrode is bimetallic strip of Cu and Ag dipped in water. What will be the E.M.F of the cell?

a) 1.10V

b) 0.76V

c) 2.34V

d) 1.24V

$E^0_{Zn/Zn^{2+}} = -0.76V$

E^0 $Fe/Fe^{2+} = 0.44V$

E^0 $Ag/Ag^+ = +0.80V$

E^0 $Cu/Cu^{++} = 0.34V$

5. Following are the values of voltage (V), current (I) at different temperatures:

V (volts)	**I (ampres)**	**t (°C)**
1.00	2.00	0
1.10	2.20	0
10.0	22.0	0
1.00	2.05	100
1.05	2.20	100
11.0	26.0	100

1.00, 1.05, and 1.10 are, say, low voltages and 10.0 and 11.0 as high voltages, t=0°C as low temperature and t=100°C as high temperature.

Match the statement with best response

Statements

Ohm's law is obeyed for

a) low V, high t

b) low V, low t

c) high V, high t

d) high V, low t

Responses

a) The data above lend support

b) The data above contradict

c) The data above neither contradict nor support the statement.

6. A source of direct electricity was applied to the two platinum electrodes dipped in an aqueons solution of $CuSO_4$. During the electrolysis, it was found that oxygen is produced at the anode and copper metal is deposited on the cathode.

Following E^0 values are given:

i. $Cu^{2+} + 2e^- \rightarrow Cu$, $E^0 = +0.34$ V

ii. $O_2 + 4H^+ (aq) + 4e^- \rightarrow 2H_2O$, $E^0 = +1.23$ V

iii. $2H_2O + 2e^- \rightarrow H_2 + 2OH^- (aq)$, $E^0 = -0.83$ V

iv. $S_2O_8^{2-} (aq) + 2e^- \rightarrow 2SO_4^{2-} (aq)$, $E^0 = +2.00$ V

We can explain the products at the electrodes as:

a) H_2O is more easily oxidized than SO_4^{-2} and Cu^{2+} is more readily reduced than H_2O

b) H_2O is more easily reduced and Cu^{2+} is more readily oxidized.

c) Data are insufficient to conclude.

7. Electrons move freely in a conductor. So in all the conductors, electrical charges are carried by electrons.

a) The conclusion is logically sound

b) Conclusion is true, because statement is true.

c) No conclusion can be reached without considering more experimental evidence.

d) Conclusion is not derived logically.

8. You are faced with a conflicting concept. What often do you do?

a) Explore it thoroughly by yourself and try to test.

b) Admit what the book says and feel no need to try it.

c) Admit what the teacher says and feel no need to test it.

d) Explore it by yourself, discuss with your friends and teacher and try to test it.

9. Two of your classmates are in disagreement regarding the temperature of a steel spoon and wooden table which are kept in a room for some time. One says that steel spoon feels colder on touching with finger, hence it is at lower temperature. The other says that both are at the same temperature. How would you resolve the conflict?

   a) By searching the answer in the text-books.
   b) By taking the help of your teacher.
   c) By measuring the temperature with a thermometer.
   d) By feeling the objects yourself.

10. Make True/False with explanation

   a) Battery delivers a constant current whatever the circuit to which it is connected.
   b) Battery goes dead when all of the electrons are used up from inside the battery.
   c) You can start a Maruti 800 by 12 V series combination of 1.5 V dry cells.

Appendix – 3

STUDENTS CONSTRUCTION SHEET
(Chemistry)

Name of the School: ____________________

Name of the Student: ____________________

Class and Section: ____________________

Day and Date: ____________________

General Problem

You are familiar with a dry cell or a battery. You may like to design and build your own cell. What are the factors you would consider to build a galvanic cell as good as a commercial one? What are its E.M.F., potential difference, current characteristics, etc?

Suggested Activities

Activity (A) Constructing of Zn-Cu galvanic cell and measuring its E.M.F.

Activity (B) Constructing galvanic cells with different combinations of electrodes and measuring their E.M.Fs.

Activity (C) Effect of concentration variation on the value of electrode potential of Zn/Zn^{2+} electrode

Activity (D). Studying parameters affecting the delivery of the current in a galvanic cell leading to designing and building an effective cell.

STUDENT'S CONSTRUCTION SHEET
(Physics)

Name of the School: ______________________________

Name of the Student: ______________________________

Class and Section: ______________________________

Day and Date: ______________________________

Suggested Activities

Activity (A)	Studying variation of resistances of metallic wires with different length and cross-section area.
Activity (B)	Studying combination of resistance in series and parallel
Activity (C)	Studying internal resistance of a galvanicl cell and its current delivery.

EXPLORATION PHASE

Q.1. Describe the purpose/important function of each of materials provided for the activities.

S,No.	Individual	After Group Discussion	After Class Discussion

Q.2. What hypothesis would you make from these activities?

Activity	Individual	After Group Discussion	After Class Discussion
(A)			
(B)			
(C)			
(D)			

Q.3. How would you set up the apparatus for performing the activity to test your hypothesis?

Activity	Individual	After Group Discussion	After Class Discussion
(A)			
(B)			
(C)			
(D)			

Q.4. On what basis will you analyse and conclude the results?

Activity	Individual	After Group Discussion	After Class Discussion
(A)			
(B)			
(C)			
(D)			

ACTIVITY - A

CONSTRUCTING Zu-Cu ELECTROCHEMICAL CELL.

EQUIPMENT AND CHEMICALS

1. One (100 ml) beaker
2. Agar Agar gel in contact with KNO_3 solution (saturated)
3. 2 metal electrodes - Zn and Cu (1 each)
4. Multimeters (2)
5. 1 0M $CuSO_4$, 1.0M $ZnSO_4$
6. 2 droppers
7. LED
8. 10 Ω resistor
9. Commercial Zn/Cu cell

EXPERIMENTATION AND INTERPRETATION

Complete the following while doing the experiments.

1. Draw the diagram of the experimental set up.

2. What is the polarity (positive or negative) of the
   i. Zn electrode
   ii Cu electrode

3. What is happening on the two electrodes?
   i. Zn electrode
   ii Cu electrode

4. What is the observed value on the multimeter? What is the expected value? Compare the two values and give reasons for the difference, if any

5. What would you expect to happen if the droppers are taken out of the Agar-Agar solution? Will the reaction continue? If not, why?

6. Connect one LED, a resistor of 10 Ω and another multimeter (in DC current mode) to the two electrodes and record your observation below:-

   i. LED Glows/does not flow.

   ii. Multimeter Indicates/does not indicate current.

   iii. The reading in the multimeter, if any ______________ .

   iv. Compare the values with that of a commercial Zn/Cu Cell/dry cell.

7 What other variation do you want to observe? Write and record the values.

8. How can you improve upon the accuracy of your observations?

9. Mention what problems you faced while carrying out the experiment.

ACTIVITY - B

CONSTRUCTING OF ELECTROCHEMICAL CELLS WITH DIFFERENT COMBINATIONS OF ELECTRODES AND STUDYING THEIR ELECTRODE POTENTIALS.

EQUIPMENT AND CHEMICALS PROVIDED

1 (100 ml) Beaker

2 5 droppers

3 Clip leads (6)

4 5 metal electrodes – one each of Cu, Pb, Ag, Zn and Fe

5 Multimeter

6. 0.1M $Cu(NO_3)_2$

7 0 1M $Pb(NO_3)_2$

8 0.1M $FeSO_4$

9 0.1M $AgNO_3$

10 0.1M $Zn(NO_3)_2$

11. Conducting Agar Agar gel in contact with saturated KNO_3 solution.

EXPERIMENTATION AND INTERPRETATION

1. The cell potentials of different electrode combinations and their values.

trode 1	Electrode 2	Cell Potential measured	Polarity of the Electrode-1	Reaction at Cathode	Reaction at anode
	Pb/Pb^{++}				
	"				
	"				

2. Arrange the values of electrode potential obtained in increasing/ decreasing order.

Electrode	Potential
1	
2.	
3.	
4	
5.	

3. How can you justify taking Pb/Pb^{++} as our reference electrode? Can you suggest some other electrode as a reference electrode?

4. Comment on the electrode potential being positive for some and negative for other?

5. What e.m f. would you observe between Zn/Zn^{2+} and $Cu/H^{+}(aq)$? What difference would it make if you take Cu/Cu^{2+} (aq). Explain.

ACTIVITY - C

STUDYING EFFECT OF CONCENTRATION VARTIATION OF AN ELECTROLYTE ON THE VALUE OF ELECTRODE POTENTIAL.

EQUIPMENT AND CHEMICALS PROVIDED

1. 8 droppers
2. Beaker
3 Multimeter
4. Cu electrode
5. Zn electrode
6 Agar Agar gel in contact with saturated KNO_3 solution.
7. $CuSO_4$ solution - 1M, ½M, 1/5M, ⅒ M, 1/50M, 1/100M
8. ZnSO4 solution - 1M

EXPERIMENTATION AND INTERPRETATION

E_{cell} values for various combinations of Cu/Cu^{++} electrode with Zn/Zn^{++} electrode in the tabular form

Electltode 1 Cu/Cu^{++}	Electode 2 Zn/Zn^{++}	Ecell
Cu/Cu^{++} (1 0M)		
Cu/Cu^{++} (0 5M)		
Cu/Cu^{++} (0.2M)		
Cu/Cu^{++} (0.1M)		
Cu/Cu^{++} (0.02M)		
Cu/Cu^{++} (0.01M)		

1. Plot a graph between the measured cell potential and log c (conc. of Cu^{++}).

2. Why do you observe the variation? Justify you answer

3. What will be the value of E_{cell} if you replace $ZnSO_4$ solution by water? Explain.

ACTIVITY - D

STUDYING EFFECT OF SURFACE AREA, INTERNAL RESISTANCE OF THE CELL ON THE FLOW OF CURRENT.

EQUIPMENT AND CHEMICALS PROVIDED

1. 10 Ω resistors
2. Two multimeters
3. Cu vessels of different sizes/Dry cell
4. Daniell cell
5. Zn electrode
6. $CuSO_4$ (1M)
7. $ZnSO_4$ (1M)
8. Droppers with Agar plug
9. Connecting wires

EXPERIMENTATION AND INTERPRETATION

Note : [*May combine with construction sheet (Physics)*]

1. Construct electrochemical cells with each of the Cu vessels given and compare their V and I values with the commercial Daniell cell and Dry cell.

Cell	Pot. difference V	Current I
A		
B		
C		

2. Connect a resistor of 10 Ω and two multimeters (one in parallel and another in series to electrochemical cell) and note down their V and I values. Repeat the observation with two 10 Ω resistors in series. Note the readings in the table.

3. Explain the observed values in all the cases.

4. On which factors the E.M.F., Potential difference and current depend?

5 How would you proceed to build your own commercial cell. What parameters would you control for getting appreciable current at constant voltage difference?

ACTIVITY B-I

STUDYING VARIATION OF RESISTANCES OF METALLIC WIRES WITH LENGTHS AND AREAS OF CROSS-SECTION.

In the previous activity (Activity-A,) you have differentiated materials on the basis of their conductivity.

Let us now investigate the variation in resistance with the length of conductor (Nichrome wire) and area of cross section

MATERIALS PROVIDED

1. 4 pieces of nichrome wire of same length and different diameters
2. One long Nichrome wire of uniform area of cross section whose length can be varied.
3. Multimeters (2)
4. One way key
5. Rheostat
6. Screw
7. Meter scale/vernier calliper
8. Connecting wires and clips

EXPERIMENTATION AND INTERPRETATION

1. Draw the circuit diagram for the experimental set up.

2. Record you observations (values of V, I & R) for all the given samples.

3 Plot and discuss the V and I graph for the observed values.

4 Based on your observations, what is the relation between (a) Resistance (R) and length (1) of a conductor? (b) Resistance (R) and area of cross section (A) of a conductor.

ACTIVITY B-II

REPEAT ACTIVITY B-I FOR WIRES HAVING SAME LENGTH AND AREA OF CROSS SECTION BUT DIFFERENT MATERIALS.

MATERIALS PROVIDED

1 Wire of different materials of same length and area of cross section
2. Rheostat
3. Battery
4 Key
5. Connecting wire, clips.
6 Multimeter (2).

EXPERIMENTATION AND INTERPRETATION

1. Observe and tabulate your results. (values of V,I,R)

2. What conclusions do you draw by comparing activity B-I.

ACTIVITY - C

STUDYING COMBINATION OF RESISTORS IN SERIES AND PARALLEL.

You are familiar with the fact that resistivity (or conductivity) of a conductor (resistor) is dependent of the electric field existing in it It is specific for a given material, at a given temperature

If resistivity is denoted by ρ (rho), the resistance R of a given conductor is given by $R = \rho\frac{\ell}{A}$

Where, ℓ is the length of the conductor and A is its area of cross section

Now several resistors may be combined to form a network. We will investigate here the ways of combining resistance and the current which flows through them.

Two or more resistances are said to be connected in series when the same current passes through all the resistors.

For example, if two resistors are connected as shown below, they are said to be connected in series, as shown below

The resistance across AB is equivalent resistance of the combination.

Two or more resistance are said to be connected in parallel if the same potential difference exists across the resistors

For example, as shown in the diagram below

Three resistances are connected in parallel, and resistance R across AB is the resistance of the combination.

MATERIALS PROVIDED

1 Multimeter
2. Battery
3. Rheostat
4 One way key
5. Crocodile clips and connecting wires
6. Standard resistances
(1Ω, 2Ω, 5Ω, 1kΩ etc)

EXPERIMENTATION AND INTERPRETATION

Answer these questions while carrying out the experiment

1 Draw the circuit diagram of the actual set-ups in the space provided

2 What did you notice about the equivalent resistance of the combination. Note down in tabular from.

3 Compare the equivalent resistance when two resistances are connected in parallel and in series.

4. What expression can you write for total resistance for a combination of resistance in series?

5 What expression represents the total resistance for a combination of resistance in parallel?

ACTIVITY - D

STUDYING THE INTERNAL RESISTANCE OF A COMMERCIAL CELL AND THE ONE YOU CONSTRUCTED. STUDY THE VARIATION OF THE CURRENT CONTINUOUSLY DRAWN THROUGH DIFFERENT RESISTORS AND CHANGES IN POTENTIAL DIFFERENCE VERSUS TIME FOR 1 TO 2 HRS FOR THESE CELLS.

EXPERIMENTATION AND INTERPRETATION

Observation table for Commercial (C : Daniell and Dry Cells) and Lab Constructed (L) Cell :

Time (min)	R (ohm)		i mA		V volt		r (internal resistance) ohm	
	C	L	C	L	C	L	C	L

Based on your observations answer these questions :

1. Comment on the constancy of potential difference and current delivered in the two cases.

2. Why does the internal resistance change ?

3 What design you would suggest for viable commercial cell out of the one you constructed?

Appendix – 4

ASSESSMENT SHEET

Tick One

Name of the School ____________________ - Study Group - Physics
Name of the Teacher ____________________ - Control Group - Chemistry

S No	*Name of the student*	*Pre-test score Marks*	**INSTRUCTIONAL PHASE**								*Post-test Phy/ Chem Marks*	*Post-test (C) Marks*
			Exploration			*Elaboration*			*Transformation*			
			Through Group Discussion	*Through Home Assignments*	*Motivational Effects, Self-direction, Interests, etc.*	*Group Work Self-Initiation*	*Interpretation*		*Written*	*Oral Interview*		
							Written	*Oral Interview*				

Appendix – 5

PARTICIPATING SCHOOL TEACHERS

Shri P.L. Saini
PGT in Physics
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Shri S.K. Sharma
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10. Mrs. Amarjeet Kaur
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13. Mrs. Manjusha Rawat
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14. Mrs. A. Baker
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RESOURCE PERSONS

Dr.P.S. Jaiswal
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Dr. V.K. Dhawan
Reader (Physics)
ARSD College
Dhaula Kuan, New Delhi.

Dr. Sanjiv Kumar
Sr. Lecturer
Deshbandhu College
Kalkaji, New Delhi-19.

Dr. Vijay Sharda
Reader (Chemistry)
Zakir Husain College
JLN Marg
New Delhi-2.

Prof. Ved Ratna
C-536 Saraswati Vihar
Delhi-31.

III. NCERT FACULTY AND JPF INVOLVED.

1. Prof. R.N. Mathur
   Prof. in Physics
   DESM, NCERT, New Delhi. (upto 30.6.2000)

2. Mrs. Neeru Snehi (upto 30.6.2000)
   JPF, NCERT., New Delhi.

3. Shri Bhopal Singh Rawat (from 1.9.2000 to 30.6.2001)
   JPF, NCERT
   New Delhi.

IV. PROGRAMME COORDINATOR

Prof. H.O. Gupta
DESM, NCERT,
New Delhi.

Appendix - 6

Students Electrochemical Effect Kit

List of Items

Sl. No.	Name	Specification	Checked
1.	Multimeter	2 (Digital)	
2	Daniell Cell	1 (Container, Zn rod, porous pot)	
3.	Small Copper Container	1	
4.	Tube Cut	1	
5	Droppers	10	
6.	Electrodes	10 (2 each of Cu, Zn, Ag, Pb, and Fe)	
7	LED	1	
8	Resistance	4(10 Ω)	
9	Resistances	10 (2 each of 1Ω, 2Ω, 5Ω, 10Ω and 1 KΩ)	
10	Copper Connecting Wires	8 (each having 30 cm. length)	
11	Pairs of Crochodile Clipped Wires	3	
12	Resistance Wires	6 (Two each of Copper, Eureka, Nichrome, having dia and length 0 5mm and 25cm respectively).	
13	Resistance Wires	10- Nichrome (2 each having dia and length) (1) 0 14mm , 25cm (2) 0 30mm., 25cm (3) 0 38mm., 25cm. (4) 0.5mm., 25cm (5) 0 5mm , 100cm	
14	Rheostat	1	
15.	One Way Key	1	
16	Beaker	1 (Plastic, 100 ml)	
17	Dry Cells	2 (1 5 V)	
18	Cell Holder	1	
19	Agar – Agar	100 g per School (with two kits)	
20.	Ag NO_3	20 g per School. (with two kits).	

Name of the School.
Name of the Teachers:

Received two kits

Dated.

Signature